



UNESCO-NIGERIA TECHNICAL &
VOCATIONAL EDUCATION
REVITALISATION PROJECT-PHASE II



NATIONAL DIPLOMA IN BUILDING TECHNOLOGY



BASIC PRINCIPLES IN SURVEYING I

COURSE CODE: SUG 101

YEAR I- SE MESTER I

THEORY/PRACTICALS

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WEEK ONE:

INTRODUCTION

- Surveying is defined as “taking a general view of, by observation and measurement determining the boundaries, size, position, quantity, condition, value etc. of land, estates, building, farms mines etc. and finally presenting the survey data in a suitable form”. This covers the work of the valuation surveyor, the quantity surveyor, the building surveyor, the mining surveyor and so forth, as well as the land surveyor.
- Another school of thought define surveying “as the act of making measurement of the relative position of natural and man made features on earth’s surface and the presentation of this information either graphically or numerically.

The process of surveying is therefore in three stages namely:

(i) Taking a general view

This part of the definition is important as it indicates the need to obtain an overall picture of what is required before any type of survey work is undertaken. In land surveying, this is achieved during the reconnaissance study.

(ii) Observation and Measurement

This part of the definition denotes the next stage of any survey, which in land surveying constitutes the measurement to determine the relative position and sizes of natural and artificial features on the land.

(iii) Presentation of Data:

The data collected in any survey must be presented in a form which allows the information to be clearly interpreted and understood by others. This presentation may take the form of written report, bills of quantities, datasheets, drawings and in land surveying maps and plan showing the features on the land.

CLASSIFICATION OF SURVEYORS

Surveying is made up of various specializations known as sectors or classes as shown below:

1. General Practice Surveyors:

- Surveyors under this class are mostly concerned with valuation and investment. Valuation surveyors deal with property markets, land and property values, valuation procedures and property law. Investment surveyors help investors to get the best possible return from property.
- They handle a selection of properties for purchase or sale by pension funds, insurance companies, charities and other major investors. They also specialize in housing policy advice, housing development and management.

2. Planning and Development Surveyors

- They are concerned with preparing planning applications and negotiating with local authorities planners to obtain planning permission.

3. Building Surveyors

- Their work involves advising on the construction, maintenance, repair and refurbishment of all types of residential and commercial property.
- The analysis of building defects is an important part of a building surveyors discipline.

4. The Quantity Surveyors

- They evaluate project cost and advice on alternative proposals. They also



ensure that each element of a project agrees with the cost plan allowance and that the overall project remains within budget.

5. Rural Practice Surveyors:

- Surveyors in rural practice advice land owners, farmers and others with interests in the country side.
- They are responsible for the management of country estates and farms, the planning and execution of development schemes for agriculture, forestation, recreation, sales of properties and live stock.

6. Mineral Surveyors

- They plan the development and future of mineral workings. They work with local authorities and the land owners on planning applications and appeals, mining laws and working rights, mining subsidence and damage, the environmental effects of land and rehabilitation of derelict land and deep underground mines.

7. Land surveyors:



- They measure land and its physical features accurately and record them in the form of a map or plan for the purpose of planning new building and by local authorities in managing roads, housing estates, and other facilities.
- They also undertake the positioning and monitoring for construction works.

BRANCHES OF SURVEYING

Surveying

Aerial
Surveying

Land
Surveying

Hydrographic
Surveying

Geodetic
Surveying

Plane
Surveying

Cadastral
Surveying

Topographi
c
Surveying

Engineerin
g
Surveying

1. Aerial Surveying

- Aerial surveys are undertaken by using photographs taken with special cameras mounted in an aircraft viewed in pairs. The photographs produce three-dimensional images of ground features from which maps or numerical data can be produced usually with the aid of stereo plotting machines and computers.



2. Hydrographic Surveying (Hydro-Survey)



- Hydro survey is undertaken to gather information in the marine environment such as mapping out the coast lines and sea bed in order to produce navigational charts.

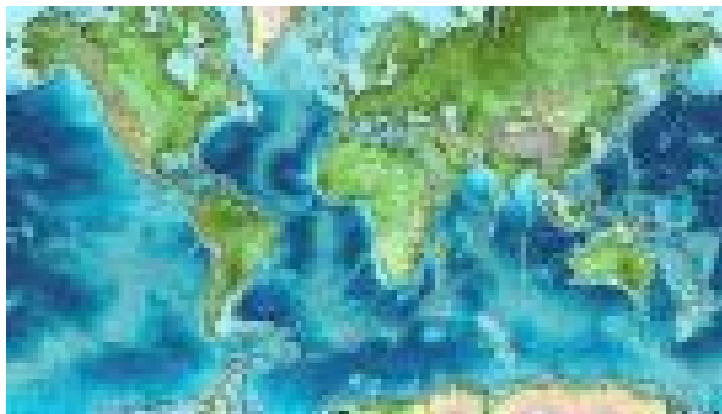


- It is also used for off shore oil exploration and production, design, construction and maintenance of harbours, inland water routes, river and sea defence, pollution control and ocean studies.



3. Geodetic Survey:

- In geodetic survey, large areas of the earth surface are involved usually on national basis where survey stations are precisely located large distances apart. Account is taken of the curvature of the earth, hence it involves advanced mathematical theory and precise measurements are required to be made.
- Geodetic survey stations can be used to map out entire continent, measure the size and shape of the earth or in carrying out scientific studies such as determination of the Earth's magnetic field and direction of continental drifts.



4. Plane Surveying

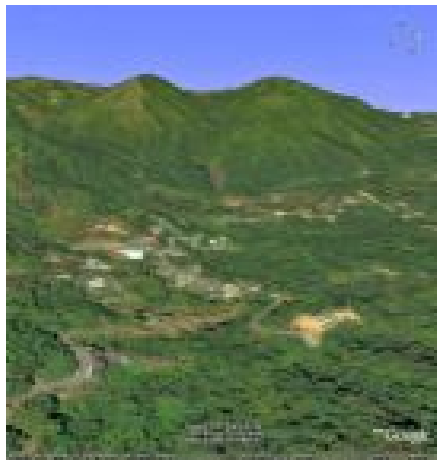
- In plane surveying relatively small areas are involved and the area under consideration is taken to be a horizontal plane. It is divided into three branches.
 - Cadastral surveying
 - Topographical surveying
 - Engineering surveying

5. Cadastral surveying

- These are surveys undertaken to define and record the boundary of properties, legislative area and even countries.
- It may be almost entirely topographical where features define boundaries with the topographical details appearing on ordinance survey maps.
- In the other hand, accurately surveyed beacons or markers define boundaries, corner or line points and little account may be taken of the topographical features.

6. Topographical Survey

- These are surveys where the physical features on the earth are measured and maps/plans prepared to show their relative positions both horizontally and vertically.



- The relative positions and shape of natural and man –made features over an area are established usually for the purpose of producing a map of the area of for establishing geographical information system.

8. Engineering Survey

- These are surveys undertaken to provide special information for construction of Civil Engineering and building projects.
- The survey supply details for a particular engineering schemes and could include setting out of the work on the ground and dimensional control on such schemes.

Reconnaissance:

- This is an exhaustive preliminary survey of the land to be surveyed. It may be either ground reconnaissance or aerial reconnaissance survey.

- Reconnaissance is made on arrival to site during which an overall picture or view of the area is obtained. The most suitable position of stations is selected, the purpose of the survey and the accuracy required will be drawn, and finally the method of observation will be established.

Objectives of reconnaissance

1. To ascertain the possibility of building or constructing route or track through the area.
2. To choose the best one or more routes and record on a map
3. To estimate probable cost and draft a report.

WEEK TWO

BASIC PRINCIPLES IN SURVEYING

PRINCIPLE OF WORKING FROM WHOLE TO PART

- It is a fundamental rule to always work from the whole to the part. This implies a precise control surveying as the first consideration followed by subsidiary detail surveying.
- This surveying principle involves laying down an overall system of stations whose positions are fixed to a fairly high degree of accuracy as control, and then the survey of details between the control points may be added on the frame by less elaborate methods.
- Once the overall size has been determined, the smaller areas can be surveyed in the knowledge that they must (and will if care is taken) put into the confines of the main overall frame.
- Errors which may inevitably arise are then contained within the framework of the control points and can be adjusted to it. Thus they have no chance of building up on accumulating throughout the whole survey.

IMPORTANCE OF SCIENTIFIC HONESTY

- Honesty is essential in booking notes in the field and when plotting and computations in the office. There is nothing to be gained from cooking the survey or altering dimensions so that points will tie-in on the drawing. It is utterly unprofessional to betray such trust at each stage of the survey.
- This applies to the assistants equally as it does to the surveyor in charge. Assistants must also listen carefully to all instructions and carry them out to the later without questions.

CHECK ON MEASUREMENTS

- The second principle is that; all survey work must be checked in such away that an error will be apparent before the survey is completed.
- Concentration and care are necessary in order to ensure that all necessary measures are taken to the required standard of accuracy and that nothing is omitted. Hence they must be maintained in the field at all times.
- Surveyor on site should be checking the correctness of his own work and that of others which is based on his information.

- Check should be constantly arranged on all measurements wherever possible. Check measurements should be conducted to supplement errors on field. Pegs can be moved, sight rails altered etc.
- Survey records and computations such as field notes, level books, field books, setting out record books etc must be kept clean and complete with clear notes and diagrams so that the survey data can be clearly understood by others. Untidy and anonymous figures in the field books should be avoided.
- Like field work, computations should be carefully planned and carried out in a systemic manner and all field data should be properly prepared before calculations start. Where possible, standardized tables and forms should be used to simplify calculations. If the result of a computation has not been checked, it is considered unreliable and for this reason, frequent checks should be applied to every calculation procedure.
- As a check, the distances between stations are measured as they are plotted, to see that there is correspondence with the measured horizontal distance. Failure to match indicates an error in plotting or during the survey.
- If checks are not done on observations, expensive mistake may occur. It is always preferable to take a few more dimensions on site to ensure that the survey will resolve itself at the plotting stage, rather than to retire to site for taking more measurements when things do not be in on the drawing board which can often be expensive besides the frustration and time loss.

ACCURACY AND PRECISION

These terms are used frequently in engineering surveying both by manufacturers when quoting specifications for their equipments and on site by surveyors to describe results obtained from field work.

- Accuracy allows a certain amount of tolerance (either plus or minus) in a measurement, while;
- Precision demands exact measurement. Since there is no such things as an absolutely exact measurement, a set of observations that are closely grouped

together having small deviations from the sample mean will have a small standard error and are said to be precise.

ECONOMY OF ACCURACY AND ITS INFLUENCE ON CHOICE OF EQUIPMENTS

- Survey work is usually described as being to a certain standard of accuracy which in turn is suited to the work in hand. Bearing in mind the purpose for which the survey is being made, it is better to achieve a high degree of accuracy than to aim for precision (exactness) which if it were to be altered would depend not only on the instrument used but also on the care taken by the operator to ensure that his work was free from mistake.
- Always remember that, the greater the effort and time needed both in the field and in the office, the more expensive to survey will be for the client. The standard accuracy attained in the field must be in keeping with the size of the ultimate drawings.
- The equipment selected should be appropriate to the test in hand. An important factor when selecting equipment is that the various instruments should produce roughly the same order of precision. A steel chain best at an accuracy of 1/500 to 1/1000 would be of little use for work requiring an accuracy of 1/1000. Similarly, the theodolite reading to one second would be pointless where a reading to one minute is sufficient.
- Having selected the equipment necessary, the work should be thoroughly checked and if found wanting should be adjusted, repaired or replaced or have allowance calculated for its deficiencies. This task will be less tedious if field equipment is regularly maintained.

ERRORS IN SURVEYING

- Surveying is a process that involves observations and measurements with a wide range of electronic, optical and mechanical equipment some of which are very sophisticated.
- Despite the best equipments and methods used, it is still impossible to take observations that are completely free of small variations caused by errors which must be guarded against or their effects corrected.

TYPES OF ERRORS

1. Gross Errors

- These are referred to mistakes or blunders by either the surveyor or his assistants due to carelessness or incompetence.
- On construction sites, mistakes are frequently made by in – experienced Engineers or surveyors who are unfamiliar with the equipment and method they are using.
- These types of errors include miscounting the number of tapes length, wrong booking, sighting wrong target, measuring anticlockwise reading, turning instruments incorrectly, displacement of arrows or station marks etc.
- Gross errors can occur at any stage of survey when observing, booking, computing or plotting and they would have a damaging effect on the results if left uncorrected.
- Gross errors can be eliminated only by careful methods of observing booking and constantly checking both operations.

2. Systematic or Cumulative Errors

- These errors are cumulative in effect and are caused by badly adjusted instrument and the physical condition at the time of measurement must be considered in this respect. Expansion of steel, frequently changes in electro magnetic distance (EDM) measuring instrument, etc are just some of these errors.
- Systematic errors have the same magnitude and sign in a series of measurements that are repeated under the same condition, thus contributing negatively or positively to the reading hence, makes the readings shorter or longer.
- This type of error can be eliminated from a measurement using corrections (e.g. effect of tension and temperature on steel tape).
- Another method of removing systematic errors is to calibrate the observing equipment and quantify the error allowing corrections to be made to further observations.

- Observational procedures by re-measuring the quantity with an entirely different method using different instrument can also be used to eliminate the effect of systematic errors.

3. Random or Compensating Errors

- Although every precaution may be taken certain unavoidable errors always exist in any measurement caused usually by human limitation in reading/handling of instruments.
- Random errors cannot be removed from observation but methods can be adopted to ensure that they are kept within acceptable limits.
- In order to analyze random errors or variable, statistical principles must be used and in surveying their effects may be reduced by increasing the number of observations and finding their mean. It is therefore important to assume those random variables are normally distributed.

WEEK THREE

EFFECTS OF ERRORS IN LINEAR MEASUREMENT AND THEIR CORRECTIONS.

1. STANDARDIZATION

- Under a given condition, a tape has a certain nominal length which may however tend to stretch with a lot of use under field conditions. The actual length can be determined by comparing it with a known standard base or against a reference tape.
- A base line for standardizing tapes should consist of two fixed points located on site such that they are likely to be disturbed. These points could be nail in pegs, but marks set into concrete blocks or pillars are preferable. The length of the field tape is computed to the length of the baseline and the standardization correction obtained as follows:.

$$\text{Standardization} = \frac{L (L_B - L_T)}{L_B} \quad \text{----- (1)}$$

Where:-

- L = Measured length
- L_B = Length of baseline
- L_T = Length of field tape along base line.

- If a reference tape is to be used, it should not be used for any field work and should be checked by the manufacturer as often as possible.
- To avoid error, standardization should be done on smooth, flat surface such as surfaced road or foot path.
- It is obvious that every tape length measured with a tape of incorrect length would be in error (plus or minus) and the total error from this source would be in direct proportion to the number of tape length measured.
- Standardization of steel tapes should be carried out frequently for each tape at least once in every six months or whenever it is broken and mended.
- From standardization measurements a correction is computed as follows:

$$\frac{\text{True distance}}{\text{Measured length}} = \frac{\text{Actual length of the tape}}{\text{Nominal length of the tape}}$$

$$\text{Or } \frac{d_t}{d_m} = \left(\frac{L_1 \pm L}{L} \right)$$

$$\text{Where :- } \left(\frac{L_1 \pm L}{L} \right) = \frac{\pm \delta L}{L} \text{ (Error per unit length)}$$

$$= \frac{d_t}{d_m} = \left(1 \pm \frac{\delta L}{L} \right)$$

$$\therefore d_t = d_m \left(1 \pm \frac{\delta L}{L} \right) \text{ standardization correction}$$

Worked Examples

Example (1)

A chain of nominal length 20.00m when compared with a standard measures 20.05m. If this chain is used to measure a line AB and the recorded measurement is 131.35m, what is the true length of AB.

Solution A:

Nominal length of chain = 20.00m

Actual length of chain = 20.05m

Measured length = 131.35m

$$\begin{aligned} \delta L &= L_1 - L \\ &= 20.05 - 20.00 = 0.05\text{m} \end{aligned}$$

$$\text{Error per chain } \frac{\delta L}{L} = \frac{0.05}{20.00} = 0.0025\text{m}$$

$$\begin{aligned} \text{True length } d_t &= d_m \left(1 + \frac{\delta L}{L} \right) \\ &= 131.35 (1 + 0.0025) \\ &= 131.680\text{m} \end{aligned}$$

Solution B

$$\text{True distance} = \text{Actual length of chain}$$

$$\text{Measured distance} = \frac{\text{Nominal length of chain}}{\left(\frac{20.05}{20.00}\right)} = 131.680\text{m}$$

EFFECT OF STANDARDIZATION ON AREA

$$\frac{\text{True distance } (A_T)}{\text{Measured Area } (A_m)} = \left(\frac{\text{Actual length of tape/chain}}{\text{Nominal length of tape/chain}} \right)^2$$

Example (2):

A metric chain of nominal length 20.00 is found to be 16cm too long and on using it an area of 100 hectares is computed. Find the true area. (1 ha = 10000m²) NOTE: (16.6cm = 0.16m)

Solution

Nominal length of chain = 20.00m

Actual length of chain = 20.16

Measured area (A_m) = 100.00ha

True Area (A_T) = Measured Area $\left(\frac{A. L. T}{N. L. T} \right)^2$

$$= 100.00 \times \left(\frac{20.16}{20.00} \right)^2$$

$$= 100.00 \times 1.016$$

$$= 101.670\text{ha}$$

EXAMPLE (3)

- (a) A base line known to be precisely 100m long was measured with a nominal 20m tape. The observed length of the base was found to be 99.925m. What is the actual length of the tape?
- (b) The tape above was used in the measurements to provide calculated area of 3.162ha. What is the true area?

Solution

True distance = 100.00m

Measured length = 99.925m

Nominal length of tape (N.L.T) = 20.00m

$$\frac{\text{True distance}}{\text{Measured length}} = \frac{\text{A.L.T}}{\text{N.L.T}}$$

$$\frac{100.00}{99.925} = \frac{\text{A.L.T}}{20.00}$$

$$\text{A.L.T.} = 20.00 \times \frac{100.000}{99.925} = 20.015\text{m}$$

(b) $\frac{\text{True Area (AT)}}{\text{Measured length}} = \frac{\text{A.L.T}}{\text{N.L.T}}^2$

$$\frac{100.00}{99.925} = \frac{\text{A.L.T}}{20.00}$$

$$\text{A.L.T.} = 2.162 \times \frac{20.015}{20.000} = 3.16\text{ha}$$

SLOPE CORRECTION



Lengths measured on sloping land must be longer than those measured on flat land. Measurements along a slope must be therefore reduced to horizontal plane before being used for computations or plotting.

- This can be achieved by calculating a slope correction for the measured length or by measuring the horizontal equivalent of the slope directly in the field.
- On ground which is of variable slope, stepping is the best method and needs no calculation. Series of horizontal distance measurements are taken in short length against a previously lined-in ranging rods and the points on the ground below the free end are located by plumb bob or drop arrow as shown below;

Diagram

- As an alternative to stepping when measuring along regular slopes, the slope angle (θ) can be determined and the horizontal distance (D) calculated from the measured slope distance (L). The correction can be computed from:

$$\text{Slope correction} = [L (1 - \cos \theta)] \dots\dots\dots 1$$

Where:-

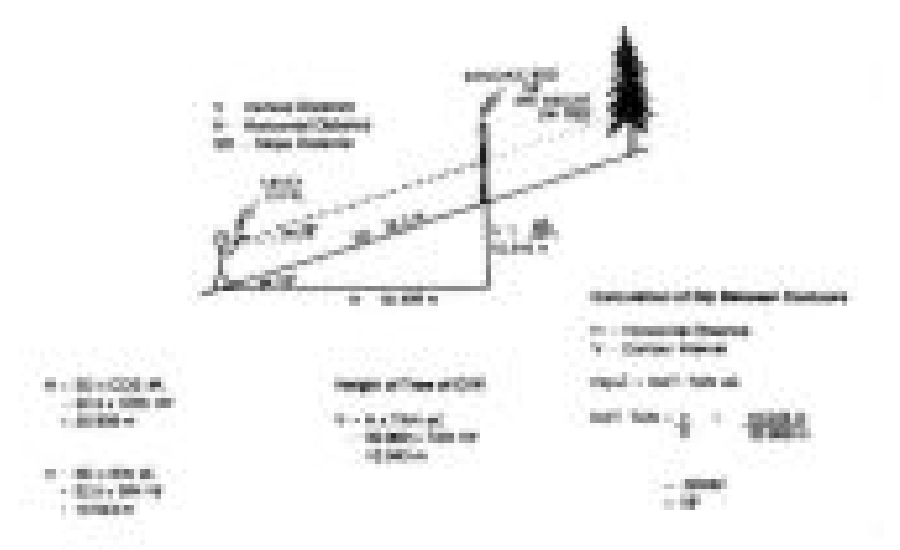
- L = measured length (slope distance)
- θ = slope angle.

The horizontal distance can be determined shown below:

$$D = L \cos \theta \dots\dots\dots 2$$

Diagram

- If the difference in light between the two stations is measured and the slope between them is uniform, then;



$$\text{Correction} = \frac{h^2}{2L} \dots\dots\dots 3$$

Where: h = difference in height

L = Measured length

$$D = L - \frac{h^2}{2L}$$

SAG CORRECTION

When the ground between two points is very irregular, surface taping can prove to be a difficult process and it may be necessary to suspend the tape above the ground between the points in order to measure the distance between them. A tape suspended in this way will sag under its own weight in the shape of a Catenary curve as shown below:

Diagram

$$\text{Sag correction} = \frac{nw^2L^3}{24T^2}$$

Where n = number of unsupported length

w = weight per metre of tape = (mg)

L = unsupported length in metres

T = Tension applied to the tape in Newton

TEMPERATURE VARIATION

Steel tapes expand or contract with temperature variation. If the temperature during measurement is different from that at which the tape was standardized the resulting error will be accumulated in direct proportion to the number of tape length measured.

- In order to improve precision, the temperature of the tape has to be recorded by using special surveying if already calibrated at a standard temperature. It is necessary to have the tape in position for some time before readings are taken to allow it to reach the ambient temperature.
- It is bad practice to measure a distance in the field in winter with a tape that has just been removed from a heated office.

The temperature correction is given by:

$$\text{Temperature correction} = \alpha L (t_f - t_s)$$

Where: α = Co-efficient of thermal expansion
 L = Length of the tape used
 t_f = Temperature during measurement
 t_s = Tape standard temperature

NOTE: - Unless the field temperature differs considerably from that at which the tape was standardized, this correction is usually negligible

TENSION CORRECTION

The tension applied to a tape should be the same as that applied when testing it against standard. Variations in tension are bound to occur even when using a spring balance, but resulting errors are small and tend to compensate each other.

If the tape is consistently pulled too hard or too lightly a cumulative error will arise and this must be guarded against particularly when using linen and plastic tapes.

Tension correction is given as:

$$\text{Tension correction} = L (T_f - T_s) A E$$

Where L = Measured length
 T_f = Tension applied to the tape (N)
 T_s = Standard tension (N)
 A = Cross sectional area of the tape (MM²)
 E = Modules of elasticity for the tape material (N/mm²)

Example 4

The following data were obtained from a survey along a slope, calculate the horizontal distance.

$$\text{Measured length} = 126.300\text{m}$$

$$\text{Slope angle} = 2^\circ 34'$$

Different in height between the two points = 5.650m

Solution

$$L = 126.300\text{m}, \theta = 2^\circ 34'$$

$$\theta = 2.567^\circ$$

$$\begin{aligned}
\text{(i). Slope correction} &= L (1 - \cos \theta) \\
&= 126.300 (1 - \cos 2.567^\circ) \\
&= 126.300 (1 - 0.9990) \\
&= 26.300 \times 0.001 \\
&= 0.126\text{m} \\
\text{Horizontal distance} &= L - \text{correction} \\
&= 126.300 - 0.126 \\
&= 126.174\text{m}
\end{aligned}$$

$$\begin{aligned}
\text{(ii) Horizontal distance (D)} &= L \cos \theta \\
&= 126.300 \times \cos 2.567^\circ \\
&= 126.300 \times 0.9990 \\
\therefore D &= 126.174\text{m}
\end{aligned}$$

$$\begin{aligned}
\text{(iii) Since the difference in height (h)} &= 5.650\text{m} \\
\text{Slope correction} - \frac{h^2}{2L} &= \frac{5.650^2}{2 \times 126.300} \\
\text{Horizontal distance (d)} &= 126.300 - 0.126 \\
&= 126.174\text{m}
\end{aligned}$$

Example (5)

A 30m tape standardized in catenary as 29.9850m at 110N is used in the field with a tension of 90N. Calculate the correction if the mass of the tape is 0.0312kg/m

Solution:-

$$\text{Sag correction} = \frac{n w^2 L^3}{24 T^2}$$

$n = 1$, standardized length (L) = 29.9850m

At $T = 110\text{N}$, mass of the tape (m) = 0.0312Kgm

Tension applied on field (T_2) = 90N

Standardized chord length with 110N = 29.9850

$$\text{Sag correction} = \frac{(0.0312 \times 9.81)^2 \times 30^3}{24 \times 110^2} = +0.0087$$

Standardized are length = 29.9850 + 0.0087

$$\begin{aligned}
 &= 29.9937\text{m} \\
 \text{Sag correction in the field} &= \frac{(0.0312 \times 9.81)^2 \times 30^3}{24 \times 902} \\
 &= 0.0130\text{m} \\
 \therefore \text{Reduced field length} &= 29.9937 - 0.0130 \\
 &= 29.980.7\text{m}
 \end{aligned}$$

EXERCISE

A steel tape of nominal length 30mm was used to measure a line AB by suspending it between supports. The following measurements were recorded.

Line	Length measured	Slope angle	Mean temp	Tension Applied
AB	29.872m	3° 40 ¹	5°C	120N

The standardized length of the tape against a reference tape was known to be 30.014m at 20°C and 50N tension.

If the tape weighs 0.17N/m and has a cross sectional area of 2mm², calculate the horizontal length of AB.

(Young modulus (E) for the tape materials is 200KN/mm² and the co-efficient of thermal expansion $\alpha = 0.000112$ per °C.

WEEK FOUR

CHAIN SURVEYING

This is the simplest and oldest form of land surveying of an area using linear measurements only. It can be defined as the process of taking direct measurement, although not necessarily with a chain.

EQUIPMENTS USED IN CHAIN SURVEYING

These equipments can be divided into three, namely

- (i) Those used for linear measurement. (Chain, steel band, linear tape)
- (ii) Those used for slope angle measurement and for measuring right angle (Eg. Abney level, clinometer, cross staff, optical squares)
- (iii) Other items (Ranging rods or poles, arrows, pegs etc).

1. Chain:-

The chain is usually made of steel wire, and consists of long links joined by shorter links. It is designed for hard usage, and is sufficiently accurate for measuring the chain lines and offsets of small surveys.



Chains are made up of links which measure 200mm from centre to centre of each middle connecting ring and surveying brass handles are fitted at each end. Tally markers made of plastic or brass are attached at every whole metre position or at each tenth link. To avoid confusion in reading, chains are marked similarly from both end (E.g. Tally for 2m and 18m is the same) so that measurements may be commenced with either end of the chain

There are three different types of chains used in taking measurement namely:

- i. Engineers chain



ii. Gunter's chain



lii Steel bands

2 Steel Bands:



This may be 30m, 50m or 100m long and 13mm wide. It has handles similar to those on the chain and is wound on a steel cross. It is more accurate and but less robust than the chain.

The operating tension and temperature for which it was graduated should be indicated on the band.

3 Tapes:

Tapes are used where greater accuracy of measurements are required, such as the setting out of buildings and roads. They are 15m or 30m long marked in metres, centimeter and millimeters. Tapes are classified into three types;



- i. **Linen or Linen with steel wire woven into the fabric;**
These tapes are liable to stretch in use and should be frequently tested for length. They should never be used on work for which great accuracy is required.
- ii. **Fibre Glass Tapes:** These are much stronger than lines and will not stretch in use.
- iii. **Steel tapes:** These are much more accurate, and are usually used for setting out buildings and structural steel works. Steel tapes are available in various lengths up to 100m (20m and 30m being the most common) encased in steel or plastic boxes with a recessed winding lever or mounted on open frames with a folding winding lever.

4. Arrows:



Arrow consists of a piece of steel wire about 0.5m long, and are used for marking temporary stations. A piece of coloured cloth, white or red ribbon is usually attached or tied to the end of the arrow to be clearly seen on the field.

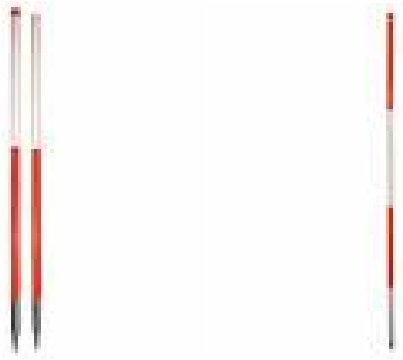
5. Pegs



Pegs are made of wood 50m x 50mm and some convenient length. They are used for points which are required to be permanently marked, such as intersection points of survey lines.

Pegs are driven with a mallet and nails are set in the tops.

6. Ranging Rod:



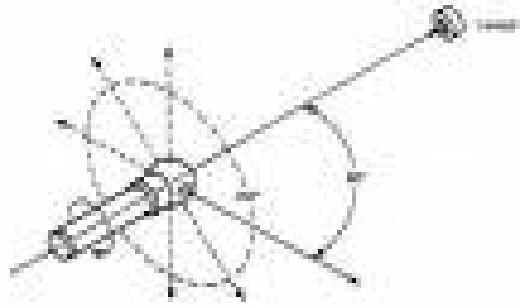
These are poles of circular section 2m, 2.5m or 3m long, painted with characteristic red and white bands which are usually 0.5m long and tipped with a pointed steel shoe to enable them to be driven into the ground. They are used in the measurement of lines with the tape, and for marking any points which need to be seen.

7. Optical Square:

This instrument is used for setting out lines at right angle to main chain line. It is used where greater accuracy is required. There are two types of optical square, one using two mirrors and the other a prism.



- The mirror method is constructed based on the fact that a ray of light is reflected from a mirror at the same angle as that at which it strikes the mirror.
- The prism square method is a simplified form of optical square consisting of a single prism. It is used in the same way as the mirror square, but is rather more accurate.



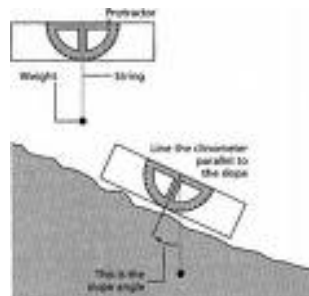
8 Cross Staff:



This consists of two pairs of vanes set at right angle to each other with a wide and narrow slit in each vane. The instrument is mounted upon a pole, so that when it is set up it is at normal eye level.

It is also used for setting out lines at right angle to the main chain line.

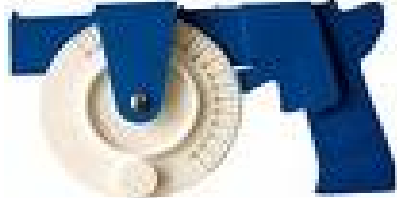
9. Clinometer



This instrument is used for measuring angles of ground slopes (slope angle). They are of several form, the common form is the **WATKING'S CLINOMETER**, which consist of a small disc of about 60mm diameter. A weighted ring inside the disc can be made to hang free and by sighting across

this graduated ring angle of slopes can be read off. It is less accurate than abney level.

9 Abney Level



This instrument is generally used to obtaine roughly the slope angle of the ground. It consists of a rectangular, telescopic tube (without lenses) about 125mm long with a graduated arc attached. A small bubble is fixed to the vernier arm, once the image of the bubble is seen reflected in the eyepiece the angel of the line of sight can be read off with the aid of the reading glass.

NECESSARY PRECAUTIONS IN USING CHAIN SURVEYING INSTRUMENTS

1. After use in wet weather, chains should be cleaned, and steel tapes should be dried and wiped with an oily rag.
2. A piece of coloured cloth should be tied to arrow (or ribbon – attached) to enable them to be seen clearly on the field.
3. Ranging rods should be erected as vertical as possible at the exact station point.
4. The operating tension and temperature for which steel bands/tapes are graduated should be indicated.
5. Linen tapes should be frequently tested for length (standardized) and always after repairs.
6. Always keep tapes reeled up when not in use.

GENERAL PROCEDURE IN MAKING A CHAIN SURVEY

- 1. Reconnaissance:** Walk over the area to be surveyed and note the general layout, the position of features and the shape of the area.
- 2. Choice of Stations:** Decide upon the framework to be used and drive in the station pegs to mark the stations selected.
- 3. Station Marking:** Station marks should where possible be tied - in to a permanent objects so that they may be easily replaced if moved or easily found during the survey. In soft ground wooden pegs may be used while rails may be used on roads or hard surfaces.
- 4. Witnessing:** This consists of making a sketch of the immediate area around the station showing existing permanent features, the position of the stations and its description and designation. Measurements are then made from at least three surrounding features to the station point and recorded on the sketch.

The aim of witnessing is to re-locate a station again at much later date even by others after a long interval.
- 5. Offsetting:-** Offsets are usually taken perpendicular to chain lines in order to dodge obstacles on the chain line.
- 6. Sketching** the layout on the last page of the chain book, together with the date and the name of the surveyor, the longest line of the survey is usually taken as the base line and is measured first.

CRITERIA FOR SELECTING A SURVEY LINES/OFFSETS

During reconnaissance, the following points must be borne in mind as the criteria to provide the best arrangement of survey lines,

- a. Few survey lines:** the number of survey lines should be kept to a minimum but must be sufficient for the survey to be plotted and checked.
- b. Long base line:** A long line should be positioned right across the site to form a base on which to build the triangles.
- c. Well conditioned triangle with angles greater than 30° and not exceeding 150° :** It is preferable that the arcs used for plotting should intersect as close as 90° in order to provide sharp definition of the stations point.

- d. Check lines:** Every part of the survey should be provided with check lines that are positioned in such a way that they can be used for off- setting too, in order to save any unnecessary duplication of lines.
- e.** Obstacles such as steep slopes and rough ground should be avoided as far as possible.
- f. Short offsets to survey lines (close feature preferably 2m) should be selected:** So that measuring operated by one person can be used instead of tape which needs two people.
- g.** Stations should be positioned on the extension of a check line or triangle. Such points can be plotted without the need for intersecting arcs.

PRACTICALS:

To identify the chain surveying instruments listed above with all parts and components. Steps to ensure safety precautions in using them to be stated.

WEEK FIVE

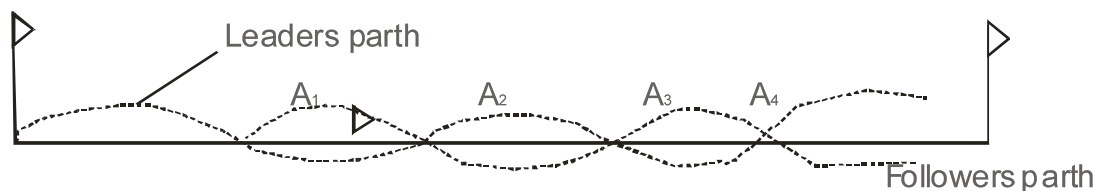
METHOD OF MAKING LINEAR MEASUREMENTS IN SURVEYING

Linear measurement is defined as the measurement of the distance between points on the surface of the earth. It can be done by one of the three methods;

- (i) Direct measurement in which a chain, tape or steel band is used (chain surveying)
- (ii) By optical means (Tacheometry)
- (iii) By Electro-Magnetic distance measurement EDM

METHOD OF MEASURING A CHAIN LINE

This is carried out by two assistants known as chain men, one acting as leading chairman and the other as follower. Ranging rods are inserted as close as possible to the station pegs in order that the position of the peg may be located from a distance. In the case of long lines, they are placed immediately between the stations and lined in by eye to enable a straight line to be measured.



- To measure line AB, having previously positioned the ranging rods at both A and B. the chain men take one end each of the chain and check for defects. The leader equips himself with ten arrows and a ranging rod, the followers also takes a ranging rod.
- The leader drags his end of the chain forward to A₁ and holds his ranging rod about one link short of the end.
- The follower holds his end of the chain firmly against stations A and the surveyor lines in the leaders pole between A and B by closing one eye, sighting poles A and B and signaling the leader till he brings his pole into line AB. (The signaling usually adopted is to swing the left arm out to the left as an instruction to the leader to move his pole in that direction. Right arm is similarly used to indicate movement to the right, while both arms extended above the head then brought down indicate that the pole is in line)

- The leader straightens the chain past the rod by sending gentle snake down the chain.
- The follower indicates the chain is straight, and the leader put arrow at the end A1. The surveyor then walks along the chain, measuring any offsets required.
- Upon the completion of these measurements, the leader drags his end to A2, taking nine arrows and his pole.
- The follower moves to A1 and puts his pole behind the arrow and the surveyor lines in from A or A1. When the arrow has been inserted at A2, the surveyor removes the arrow at A1 and proceeds to take further offset measurements.
- This procedure is repeated until the end of the line is reached or the chainman's arrows are exhausted. The collection of these arrows by the surveyor forms a check upon the number of chains measured.

METHOD OF SETTING OFFSET TO THE CHAIN LINE

Chain surveying principles have so far been applied to areas of land with straight boundaries. As most boundaries are irregular, the method of surveying their position is first to lay down a network of triangles which can be plotted and checked. From these survey lines, offsets are measured perpendicular from the chain line to points of detail.

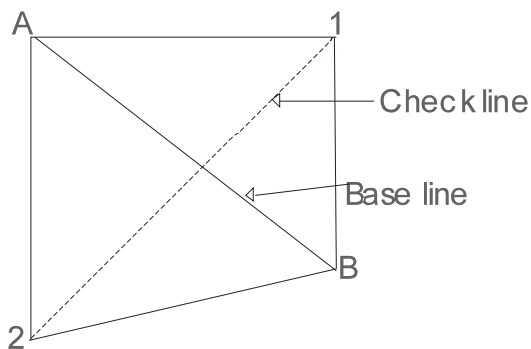
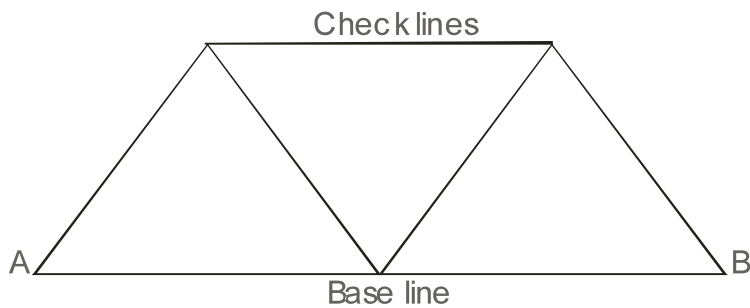
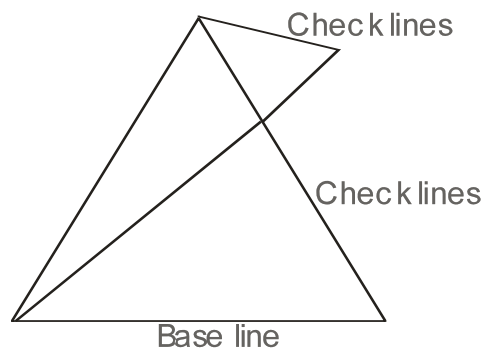
Perpendicularity may be obtained in one of the following ways;

- i. Judging with eye the right angle formed between the chain line and the tape (offset tape)
- ii. By swinging the offset tape to obtain the shortest measurement.
- iii. By setting out the right-angle with the optical square or cross –staff.
- iv. By Pythagoras's Theorem (3, 4, 5 method)

CHECK OR PROOF LINES

Check line or proof lines are used in chain surveying to ensure that the measuring and plotting of all the survey lines are correct. If mistakes were made in a measurement or in scaling, then the plot would be wrong and would not properly represent the area of land surveyed.

- To confirm whether all proper checks have been applied, each plotted line should be considered to see that lengths of measured lines were not altered from their plotting positions.
- Where checking was found inadequate, additional measurements must be made.
- Check lines need not necessary start from the corner as long as the points along the line from which they start are known they can be plotted to required positions as shown below;



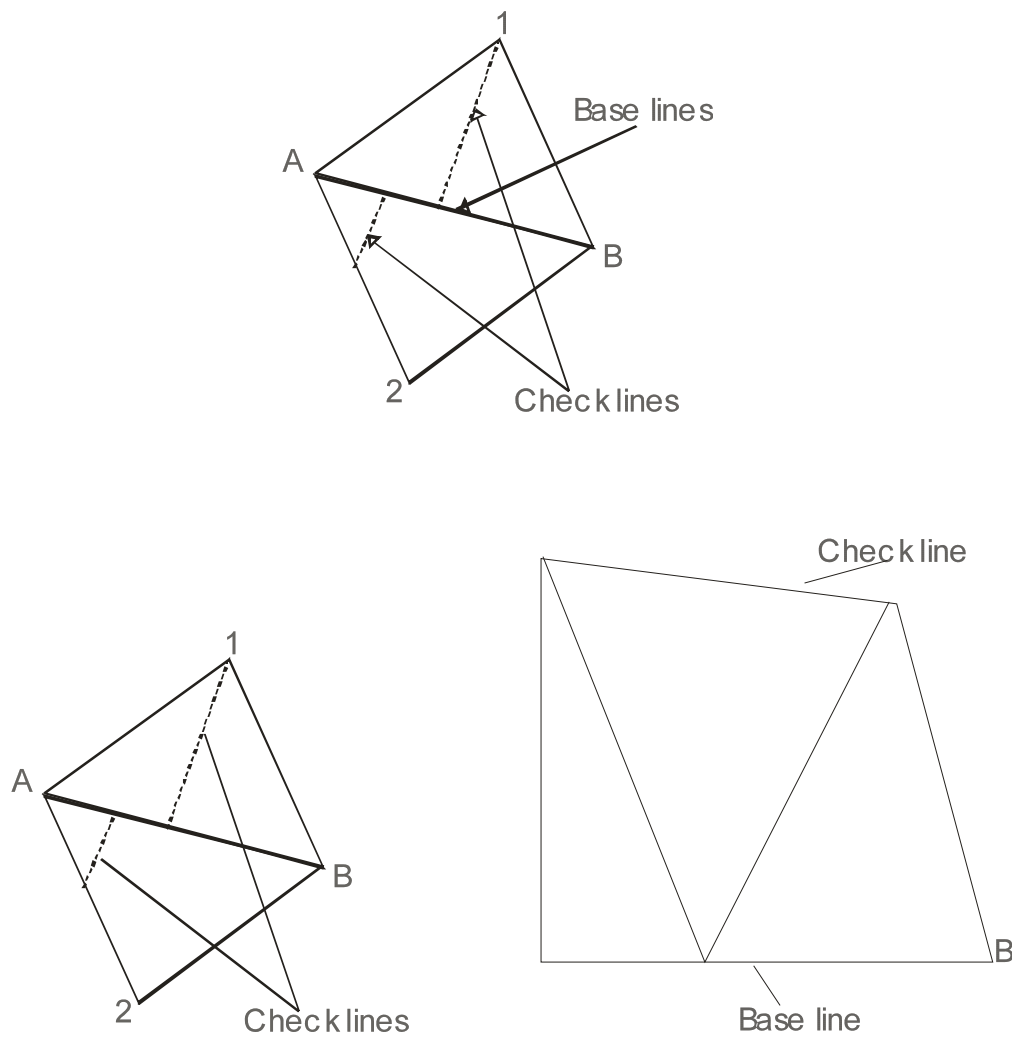


Fig Check lines used in chain surveying

FIELD NOTES

Field notes for a chain survey are made in a note book usually with a double red line ruled up the middle of each page. Booking is illustrated as shown below,

Diagram

The following information will be included to complete the field record.

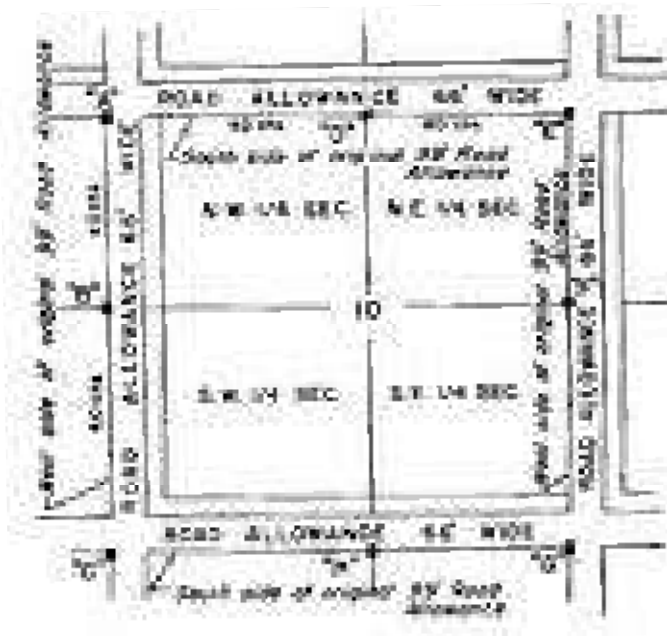
- (a) The name and location of the survey
- (b) The description and reference number of the tapes and other instruments used.

- (c) The date of the survey
- (d) The names of the survey party members
- (e) A sketch of the layout of the survey lines made during the reconnaissance.

This sketch includes:

- i. The names or letters designating stations.
 - ii. The line numbers.
 - iii. The arrow indicating the direction of the survey.
- (f) The witnessing and description of station marks.
 - (g) An index of lines and stations.
 - (h) The weather at the time of the survey and any other feature likely to offset the accuracy of the work.

The diagram below show a layout of survey lines (properly checked) relating the position of ground features.



PROCEDURE FOR TAKING FIELD NOTES

- (a) Booking must be accurate and clear. Do not sketch detail ahead of measurements and exaggerate the size of complicated features. The notes should be recorded as if another person will be doing the plotting.

- (b) It is easier to find the correct booking page while plotting if the lines are numbered connectively with a note of the line of the sketch. Alternatively, lines may be labeled by the stations through which they pass.
- (c) Sketches must be clear with no doubt about the point to which the offset is taken.
- (d) The chainage run continuously from one end of each survey line to the other with an arrow drawn on the sketch to show the direction of survey.
- (e) Only tie lines and cross measurement are sketched in the field book, offset lines are not. The offset distance is recorded clearly beside the chain line.
- (f) Always take running dimensions around building to pick up details and to check plotting and measure tie line between salient features to provide additional plotting checks.
- (g) Take care not to book in centimeters. This implies an accuracy of measurement to one millimeter.
- (h) Leave nothing to memory, including explanatory notes on details such as street names, house numbers and names, kind of tree (girth and height), types of pavement boxes etc.
- (i) Use H or 2H pencil. Harder pencils are too faint and tear damp paper and softer pencils tend to smudge.

METHOD OF PLOTTING THE SURVEY

The chains survey network of lines is first plotted in pencil As follows:

(a) Base Line

The base line is positioned on the drawing sheet in such a way that the whole area will be contained within the limits of the paper. Its full length is then scaled off, including the position of any line stations along it.

(b) Triangles

- The length of one of the lines to the first point to be plotted is extracted from the field book and set to scale on a compass to draw an arc.
- The second arc length is similarly drawn at intersection to give the plot of the first point; the position of the check line is drawn. This is scaled and confirmed to agree with the field measurement.

- Each triangle is plotted and checked in the same way until the whole framework has been plotted making sure that no check measurements have been omitted and that no plotting errors exist.

(c) Offsets

Offset measurements can be plotted using one of the two ways;

- The running chainage along the lines can be scaled off along the main lines on the plot and light pencil lines drawn perpendicular to them along which the offset distances are scaled.
- A proprietary offset scale can be used. This is a short scale graduated outwards its centre to enable offsets on either side of the survey line to be plotted. A long scale is laid on the paper parallel to the survey line so that the offset scale can slide along it with its zero coinciding all the time with the survey line whole the chainage of the offset scale can be read off the long scale.

(d) Detail Drawing

As the offsets are plotted they are joined up in pencil to correspond the features noted in the field book. Tie lines must be scaled to check the plotted positions of points as they arise.

(e) Fair Drawing

Once the pencil plot has been completed and checked the chain survey network of lines (not the offsets or tie lines) is inked in red and the fair drawing completed.

PRACTICALS:

Aim: To carryout chain survey of the College of Engineering.

APPARATUS

Chain survey apparatus listed above.

PROCEDURE

- To measure any chain line AB, having previously positioned the ranging rods at both A and B. the chain men take one end each of the chain and check for defects. The leader equips himself with ten arrows and a ranging rod, the followers also takes a ranging rod.

- The leader drags his end of the chain forward to A1 and holds his ranging rod about one link short of the end.
- The follower holds his end of the chain firmly against stations A and the surveyor lines in the leaders pole between A and B by closing one eye, sighting poles A and B and signaling the leader till he brings his pole into line AB. (The signaling usually adopted is to swing the left arm out to the left as an instruction to the leader to move his pole in that direction. Right arm is similarly used to indicate movement to the right, while both arms extended above the head then brought down indicate that the pole is in line)
- The leader straightens the chain past the rod by sending gentle snake down the chain.
- The follower indicates the chain is straight, and the leader put arrow at the end A1. The surveyor then walks along the chain, measuring any offsets required and also books the readings, sketches and records other details.
- Upon the completion of these measurements, the leader drags his end to A2, taking nine arrows and his pole.
- The follower moves to A1 and puts his pole behind the arrow and the surveyor lines in from A or A1. When the arrow has been inserted at A2, the surveyor removes the arrow at A1 and proceeds to take further offset measurements.
- This procedure is repeated until the end of the line is reached or the chainman's arrows are exhausted. The collection of these arrows by the surveyor forms a check upon the number of chains measured.
- The results obtained should be plotted and a scaled drawing prepared.

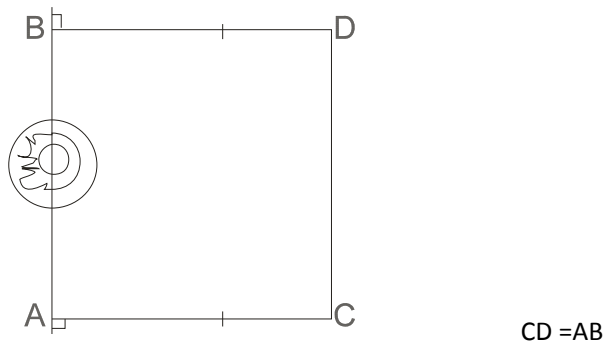
WEEK SIX

FIELD PROBLEMS IN CHAIN SURVEYING (OBSTACLES) AND WAYS OF OVERCOMING THEM

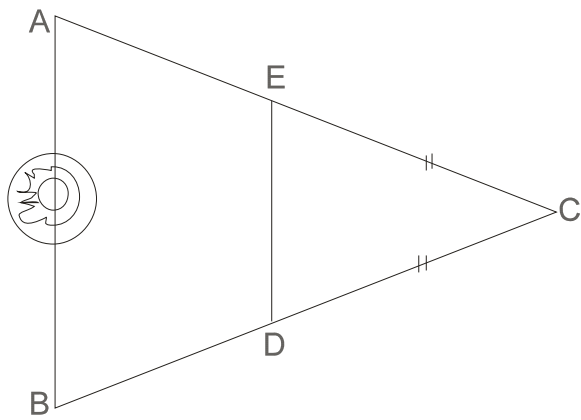
It occasionally happens that a survey has to be made on a field where obstacles are encountered like a pond, sanding crops or a small wood in the middle, river etc. In such cases, it is not possible to employ direct chaining, other methods are used for solving the problems.

1 OBSTACLES OBSTRUCTING CHAINING BUT NOT RANGING

- Suppose a line across a lake is needed AB . Perpendicular lines AC and BD are set out at A and B such that $AC = BD$. Then the line CD can be chained which is parallel and equal to AB .

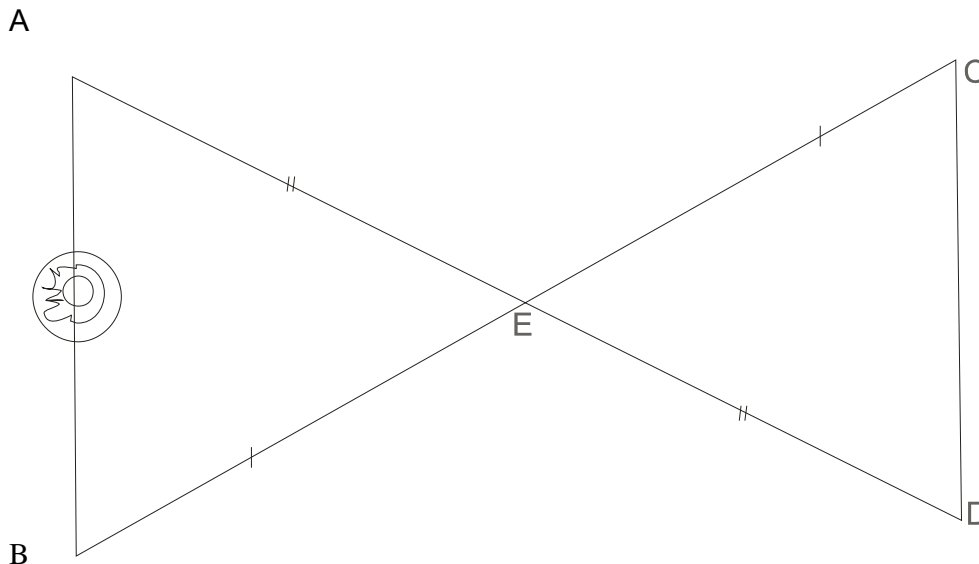


- Where setting right angles are not possible, a point C is set out clear of the obstruction. D and E are placed midway along the lines AC and CB respectively. ED is measured and twice this distance gives the length of AB . Other ratios for similar triangles such as 1:3 instead of 1:2 may be used depending on the surrounding obstructions.



$$AB = 2(ED)$$

- Alternatively, a point is chosen clear of the obstruction denoted as E. Measure $|AE|$ and $|BE|$, then extend them respectively to C and D such that $|AE| = |EC|$ and $|BE| = |ED|$. $|DC|$ is then equal and parallel to AB.

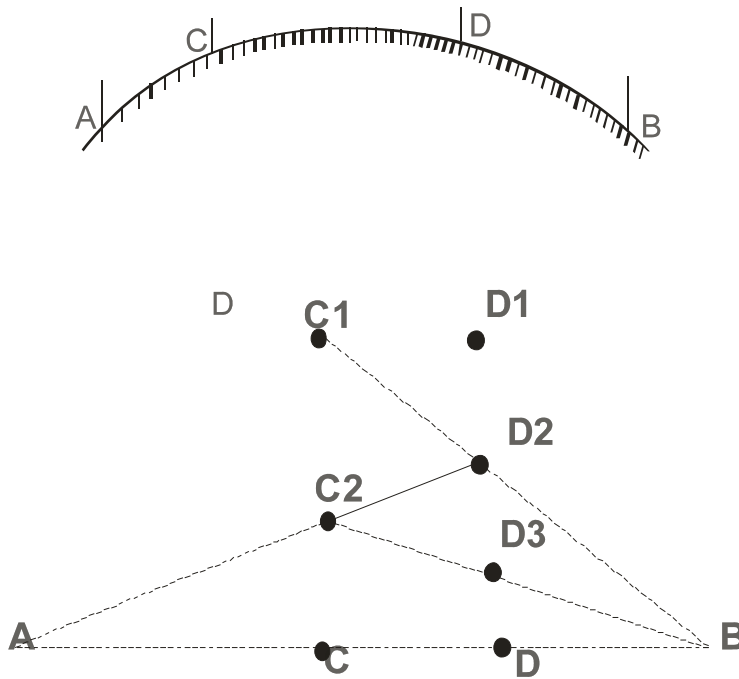


$$(AE = EC), (BE = ED), (CD = AB)$$

2 OBSTACLES OBSTRUCTING RANGING BUT NOT CHAINING (NON INTERVISIBILITY)

When both ends are visible from intermediate points on the line:-

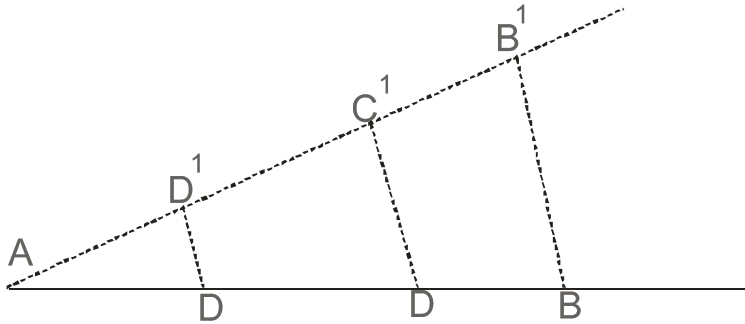
- The survey line /AB/ cannot be ranged directly because of the rising ground or hill, reciprocal ranging is usually adopted by taking up positions at C1 and D1 approximately on the line such that A and B can be seen from both points.
- From C1, D1 is ranged to D2 on line to B.
- D2 then ranges C1 to C2 on line to A and C2 then range D2 again on line to B until a position is reached where CD can be seen to be on line with /AB/. Then the whole line is properly ranged.



Where both ends are not visible from any intermediate point

- When it is impossible to adopt the method above, the line may be ranged by means of the random line method where a line /AB/ is set out clear of the obstruction in such a way that a perpendicular distance from B¹ may be dropped to the random line at B¹.
- AB¹ and B¹B are measured and from the similar triangles the perpendicular distance from C¹ to C can be calculated if the distance AC¹ is known similarly when AD¹ is known.





3. OBSTACLES OBSTRUCTING BOTH RANGING AND CHANGING

(a). Without Setting right angle

- When the ranged line proceeded as far as A and cannot go further. From the base line /AB/ a point C is then set out where $/AB/ = /AC/ = /BC/$. This results in an equilateral triangle ABC with angles 60° each.
- The line /BC/ is produced to D clear of the obstruction and another equilateral triangle EDF is constructed as before. The line /DF/ is then produced to G such that $/BD/ = /DG/$ so that the triangle BDG is also equilateral.
- Point G now lies on the extension of /AB/ but the direction of the line cannot be established until the third equilateral triangle GHK is set out. Once this is done /HG/ produced provided the extension of the line AB on the other side of the building. The obstructed length $/AH/ = /BD/ - (/AB/ + /GH/)$ because $/BD/ = /DG/ = /DB/$ by construction shown in the figure below.

Diagram

(b) Setting out right angles

- When the ranged line ends at A and can go no further, a right angles are set at A and C placed clear of the obstruction.
- Going back to a point B another right angle is set out and D is placed such that $/AC/ = /BD/$. /DC/ is now parallel to the line /AB/ and can be extended past the obstruction to E and F.
- At these points, right angles are set out to G and H such that $/EG/ = /FH/ = /AC/ = /BD/$. /GH/ provided provides the extension of the line /AB/ on the other

side of the obstacle and the measured length of /EC/ equals the obstructed length /AG/.

Diagram

NOTE

- i. The diagonals /AD/, /BC/, /GF/ and /HE/ are sometimes measured to prove the accuracy of the setting out of the right angles
- ii. Right-angle are only set out at A, B, E and F.

ERRORS IN CHAIN SURVEYING

Sources of errors

- (a) Gross errors
 - i. Displacement of arrows or station marks.
 - ii. Miscounting tape length
 - iii. Misreading the tape
 - iv. Wrong booking
- (b) Systematic error (cumulative error).
 - i. Wrong length of tape
 - ii. Poor ranging
 - iii. Poor straightening
 - iv. Slope
 - v. Sag
 - vi. Temperature variation
- (c) Random or accidental or compensating errors.
 - i. Holding and marking
 - ii. Variation in tension

WEEK SEVEN

LEVELLING



PRINCIPLES AND DEFINITIONS

Levelling is defined as the process of measuring the difference in height between points on the surface of the earth.



Level surface or Level Line

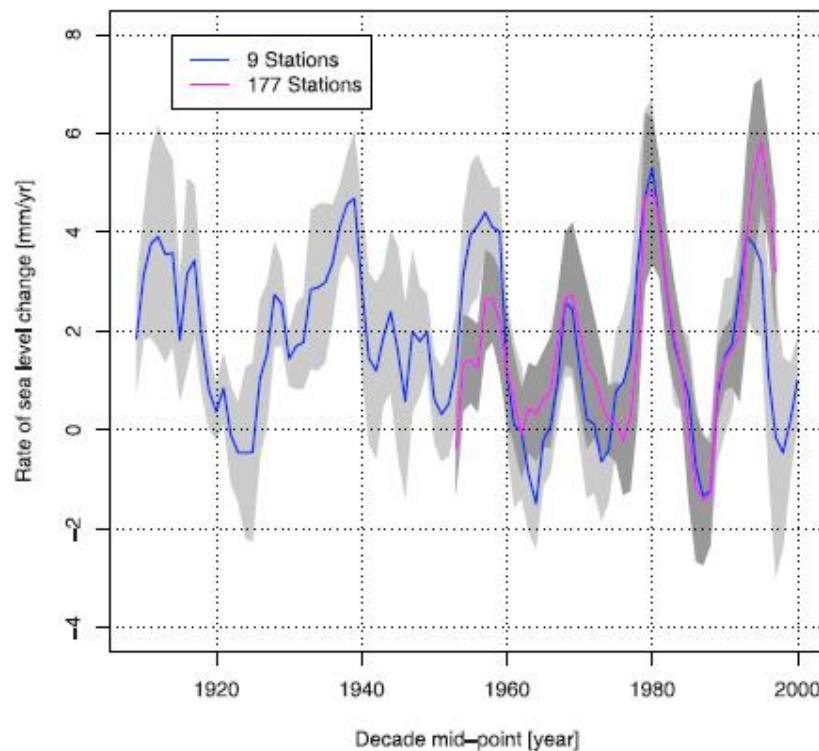
This is a surface or line in which all points are at the same height and normal or at right angle to the full of gravity as shown by a plumb line.

A Horizontal surface or Horizontal line

This is a plane flat surface or straight line which passes through a point at right angle to the pull of gravity at that point. It is therefore a tangent to the curve of a level surface.

A Datum Surface

Datum surface is any level surface to which the elevations of all points may be referred. The mean sea level is usually adopted as datum.



A Reduced Level

The reduced level of a point is its height or elevation above the surface adopted as a datum

Bench marks

Bench marks are stable reference points the reduced levels of which are accurately determined by levelling.

Back sight

This is the first reading taken with a leveling instrument in a leveling operation.

Foresight

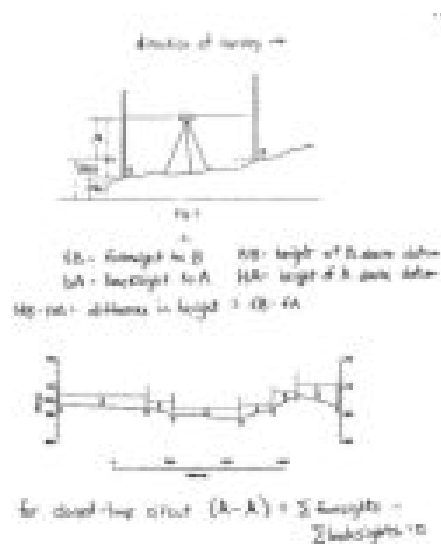
This is the last reading taken in a leveling operation.

Intermediate Sight

This is the reading taken between the back sight and foresight in a leveling operation.

Turning Point or Change Point

A change point or turning point is a staff station on which two staff readings are taken without changing the position of the instrument.



SURVEYOR'S LEVELLING INSTRUMENTS

There are three basic types of level in common use, namely.



- (a) Dumpy level
- (b) Tilting level
- (c) Automatic Level

Other types of level include:

- Hand levels, bricklayer's level, Cowley level, spirit level, digital level etc.

- **Brick layers level:**



This is the simplest form of level. It consists of glass tube filled with liquid which contains an air bubble.

This tube is set in a wooden block in such a way that when the instrument is placed upon a horizontal surface, the bubbles float centrally in the tube.

- **Cowley level**



This is a modern builder's instrument. It has no telescope nor leveling bubble but by mean of reflecting mirrors one attached to a pendulum contained in a metal case about 130mm square by 50mm thick. The instrument shows a horizontal line of sight claimed to be accurate within 6mm per 30m.

- **Spirit Level**

This consists of a glass tube in shape and filled with spirit. A small air bubble is enclosed in it. This tube is inserted in a wooden container and a metal strip is fixed at the top to protect the glass cylinder.

- **Leveling staff**

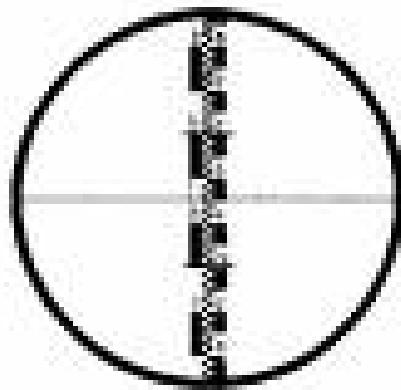
- The vertical distance above or below the horizontal surface is read off a leveling staff. It may be either telescope or folding extending to a length of 4m or 5m and graduated to be easily read in the field on view of the leveling staff graduated in metres (in 10mm division). The staff is either white or yellow.



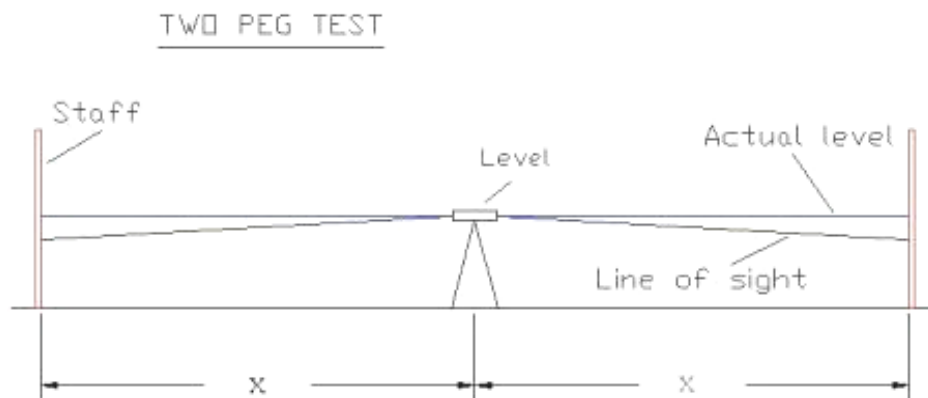
- The staff must be held vertically as any leaning of the staff will result in a level reading which is too great. Reading can be taken by holding the staff lightly between the palms of both hands on either sides of the staff.

LINE OF COLLIMATION

The line of collimation of a telescope is the line of sight defined by the optical centre of the object glass and the centre of the cross bars.



Line of collimation or line of sight is only horizontal when a level in perfect adjustment is setup and leveled. The line of sight must not be confused with a horizontal line.



As long as the distance between the two points and the level are equal then the error taken in the reading will be equal. Therefore the difference between the two points can be worked out even if the level is faulty.

WEEK EIGHT

CRITERIA FOR SELECTING LEVELLING DATUM

For all surveys a level line is chosen to which the elevation of all point is related to as datum or datum surface.

- This can be any surface but the most commonly used datum is mean sea level measured as ordinance datum. All points referred to ordinance datum are said to have their height above ordinance datum (AOD).
- On many construction and Civil Engineering sites, mean sea level is not often used as a datum for leveling. Instead, a permanent feature of some sort is chosen on which to base all works and this is given an arbitrary height (referred to as datum) to suite the site conditions.

CONSTRUCTION AND USE OF BENCH MARKS

Bench marks are permanent reference marks or points whose reduced levels are accurately determined by leveling. They are classified into two namely:

1. Permanent or ordinance bench marks (OBM), and
2. Temporary or transferred bench marks (TBM)

Permanent or ordinance bench marks (OBM)



- Ordinance bench marks are those which have been established by the ordinance survey and are based on the ordinance datum.
- The most common types are permanently marked on buildings and walls by a cut in vertical brickwork or masonry or indicated by an arrow or crows foot mark.

- On horizontal surface, OBM consist of a rivet or bolt with the position of the reduced level shown for both types.

All ordinance survey bench marks (OBM) have been in place for sometime and may be affected by physical disturbance or local subsidence. To safeguard against this, it is always advisable to include at least two OBM in leveling schemes where ordinance datum is being used.

Temporary or transferred bench marks (TBM)

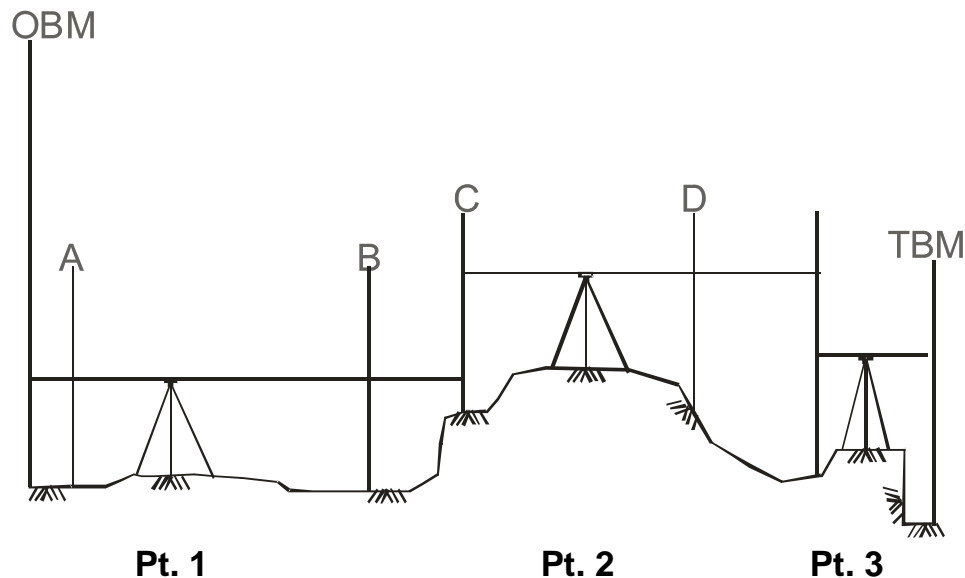


These are marks set up on stable points near construction sites to which all leveling operations on that particular site will be referred.

- These are often used when there is no ordinance bench mark (OBM) close to the site.
- The height of TBM may be assumed at some convenient value (usually 100.00m) or may be accurately established by leveling from the nearest OBM.
- The position of TBM should be fixed during the initial site reconnaissance. Permanent existing features should be used where possible. In practice, 20mm diameter steel bolts 100mm long are driven into existing door steps, foot path, low wall etc.

Any TBM set up on site must be leveled with reference to main bench mark (OBM) or some other agreed datum.

PROCEDURE IN LEVELING



- The level is set up at some convenient position P1 and a back sight was taken to the first TBM. The foot of the staff being held on TBM and the staff held vertically.
- The staff is moved to points A and B in turn and readings taken. These are the intermediate sights respectively.
- In order to read D, a change point is chosen at C and the staff is moved to C. This is the foresight for the first point (P1).
- While the staff remains at C1 the instrument is moved to another position (P2). A reading is taken from the new position of the staff at C. This is the back sight for P2.
- The staff is moved to D and E in turn and the intermediate sight readings taken respectively.
- Finally, the level is moved to P3 and a back sight is taken to E, while the foresight is also taken to the final TBM.
- The final staff position is at a point of known reduced level as leveling field work must start and finish at points of known reduced level; otherwise it is not possible to detect misclosure in the leveling.



BOOKING AND REDUCTION OF LEVEL

There are two methods of booking and reduction of level namely;

- Rise and fall method
- Height of instrument method (Height of collimation method)

HEIGHT OF COLLIMATION METHOD

The following formula will serve as a guide to the reduction of level by this method;

- (i) $B.S + R.L = H.I$
- (ii) $H.I - I.S = R.L \text{ (new)}$
- (iii) $H.I. \text{ (old)} - F.S = R.L \text{ (new) at change point}$
- (iv) $R.L. \text{ (new)} + B.S = H.I. \text{ (new)}$

Checking: The difference between the sum of B. S and the F. S should equal the known difference in height (R.L) between starting and finishing points.

Example

The following staff readings were taken along a straight length of a road.
Reduce the level and check the accuracy of the readings using Height of instrument method

Back sight	Intermediate sight	Fore sight	Reduced level	Remark
2.390			31.517	OBM
	1.985			
	1.318			
0.988		1.612		
	1.502			
	1.415			
2.420		0.316		
		0.532		TBM

Solution:

B.S	I.S	F.S	H.I	R.L	Remarks
2.390			33.907	31.517	OBM
	1.985			31.922	
	1.318			32.589	
0.988		1.612	33.283	32.295	
	1.502			31.781	
	1.415			31.868	
2.420		0.316	35.385	32.967	
		0.532		34.855	T.B.M
$\Sigma=5.798$		$\Sigma=2.460$			

Check

$$\begin{aligned}\Sigma B.S - \Sigma F.S &= R.L_{last} - R.L_{first} \\ 5.798 - 2.460 &= 34.855 - 31.517 \\ 3.338 &= 3.338\end{aligned}$$

Example

Reduce the level using H. I. Method.

B.S	I.S	F.S	H.I	R.L	Remarks
-----	-----	-----	-----	-----	---------

12.10			235.19	223.09	OBM
	4.60			230.59	
7.46		3.20	239.45	231.99	
	2.43			237.02	
3.10		7.45	235.10	232.00	
	10.45			224.65	
		12.66		222.44	TBM
$\Sigma=22.66$		$\Sigma=23.31$			

Check: $\Sigma BS - \Sigma FS = R.L_{last} - R.L_{First}$

$$22.66 - 23.31 = 222.44 - 223.09$$

$$- 0.65 = - 0.65$$

RISE AND FALL METHOD

Example (1)

The following staffs reading were taken along a straight length of a railway track. Reduce the level and check the accuracy of the readings using Rise and fall method.

B.S	I.S	F.S	Rise	Fall	R.L	Remarks
2.390					31.517	OBM
	1.985		+0.405		31.922	
	1.318		+0.667		32.589	
0.988		1.612		-0.294	32.295	
	1.502			-0.514	31.781	
	1.415		+0.087		31.868	
2.420		0.316	+1.099		32.967	
		0.532	+1.888		34.855	TBM
$\Sigma=5.798$		$\Sigma=2.460$	$\Sigma=4.146$	$\Sigma=0.808$		

NOTE: (+) donates rise and (-) fall

Checking:

$$(\sum BS - \sum FS) = (\sum Rise - \sum Fall) = (R.L_{Last} - R.L_{first})$$

$$(5.798 - 2.460) = (4.146 - 0.808) = (34.855 - 31.517)$$

$$3.338 = 3.338 = 3.338$$

Example

B.S	I.S	F.S	Rise	Fall	R.L	Remarks
2.191					49.873	OBM
	2.505			-0.314	49.559	
	2.325		+0.180		49.739	
3.019		1.496	+0.829		50.568	
	2.513		0.506		52.074	
		2.811		-0.298	50.776	TBM
$\sum=5.21$		$\sum=4.307$	$\sum=1.515$	$\sum=0.612$		

NOTE: (+) donates rise and (-) fall

Checking

$$(\sum BS - \sum FS) = (\sum Rise - \sum Fall) = (R.L_{Last} - R.L_{first})$$

$$(5.21 - 4.307) = (1.515 - 0.612) = (50.776 - 49.89)$$

$$0.903 = 0.903 = 0.903$$

Exercise:

- (a). The table below shows the result of a leveling operation to determine the reduced level of a roof. Re-book the figures by using rise and fall method and apply the necessary checks.

Back sight	Intermediate sight	Foresight	Reduced Level	Remarks
2.88			457.32	Corridor C
4.50		0.54		Step C-D
	2.86			Landing 1
4.48		0.53		First flight
				Corridor

	2.85			D
4.55		0.54		Second flight
	2.90			Landing 2
4.50		0.55		Step to E
	2.88			Corridor E
3.02		-4.89		Floor-level shed
	2.77			Roof outside shed
2.98		2.84		S.E. corner roof
	2.89			Centre S. end roof
	2.99			S.W. corner roof
	0.35			Parapet corner 1
	2.94			Centre, N. Roof
	0.27			N.E. corner roof
	2.89			Parapet corner 2
	2.98			
		1.65		

(b) The following readings were taken with a level and a 4m staff;
0.683, 1.109, 1.838, 3.399, (3.877 and 0.1451) change point, 1.405, 1.896, 2.676,
3.478, (3.999 and 1.834) change point, 0.649, 0.706.

- (i) Draw up a level book page and reduce the level by rise and fall method.
- (ii) Check the accuracy of the work.

(c) The figures tabulated below is all that remain visible on a much battered page from a leveling book owing to exposure to rain. By inspection of the remaining figures, fill in the queried entries by inserting the missing figures and apply the necessary checks.

Chainage	B.S	I.S	F.S	H.I	R.L	Remarks
1+000	2.99			222.26	?	OBM
2+000		3.24			219.02	

3+000		?			218.80	
4+000	?		4.18	221.47	218.08	
5+000		3.23			218.24	
6+000	4.01		3.15	?	217.96	
7+000		3.22			218.75	
8+000			2.48		?	
	?		?			TBM

(d). The table below shows the result of a leveling operation to determine the reduced level of a roof. Re-book the figures by using rise and fall method and apply the necessary checks.

Back sight	Intermediate sight	Foresight	Reduced Level	Remarks
2.88			457.32	Corridor C
4.50		0.54		Step C-D
	2.86			Landing 1
4.48		0.53		First flight
	2.85			Corridor D
4.55		0.54		Second flight
	2.90			Landing 2
4.50		0.55		Step to E
	2.88			Corridor E
3.02		-4.89		Floor-level shed
	2.77			Roof outside shed
2.98		2.84		S.E. corner roof
	2.89			Centre S. end roof
	2.99			S.W. corner roof
	0.35			Parapet corner 1

	2.94			Centre, N. Roof
	0.27			N.E. corner roof
	2.89			Parapet corner 2
	2.98			
		1.65		

TERTIARY LEVELLING

AIM: Carry out tertiary levelling, reduction and adjustment to produce elevations of all permanent stations along a circuit of about 5kms.

APPARATUS

Level, tripod, levelling staff, steel tape, linen tape, ranging pole, arrows, levelling field book, foot plate, pegs, nails and bottle cork, pen, etc.

PERSONNEL

At least six persons in a group

PROCEDURE

- (i) Selection of instrument
- (ii) Test of instrument
- (iii) Field reconnaissance
- (vi) Reconnaissance diagram /sketch
- (v) Measure the interval and set the level instrument
- (vi) Place a staff on the starting point and a staff where the interval terminates
- (vii) Observe the back staff, read and note the reading
- (viii) Observe the forward staff, read note the reading
- (ix) Reduction and adjustment

WEEK NINE:

USES OF LEVELLING

Apart from the determination of difference in level between points on earth's surface, other uses of leveling include.

- (1) Taking of longitudinal section
- (2) Cross- sections
- (3) Contouring
- (4) Setting out levels

(1) Longitudinal Section

- In Engineering Surveying, a longitudinal section (or profile) is taken along the complete length of the existing ground level. Levelling can be used to measure heights at points on the centre line so that the profile can be plotted.
- Generally, this type of section provide data for determining the most economic formation level, this being the level to which existing ground is formed by construction methods.
- The optimum position for the formation level is usually found by using a computer aided design package but the longitudinal section is sometime drawn by hand and a mass – hand diagram prepared.
- In order to be able to plot levels obtained in addition to those taken at the centerline pegs, the position of each point on the centre line must be measured with tape and recorded.
- The method of broking longitudinal section should always be by the height of collimation method since many intermediate sights will be taken

(2) Cross - sections

- In the construction of other projects such as roads and railways, existing ground level information at right angle to the centre line is required. This is provided by taking cross sections at right angles to the centre line such that information is obtained over the full width of the proposed construction.
- For the best possible accuracy in sectioning, a cross–section should be taken at every point leveled on the longitudinal section. In order to reduce the

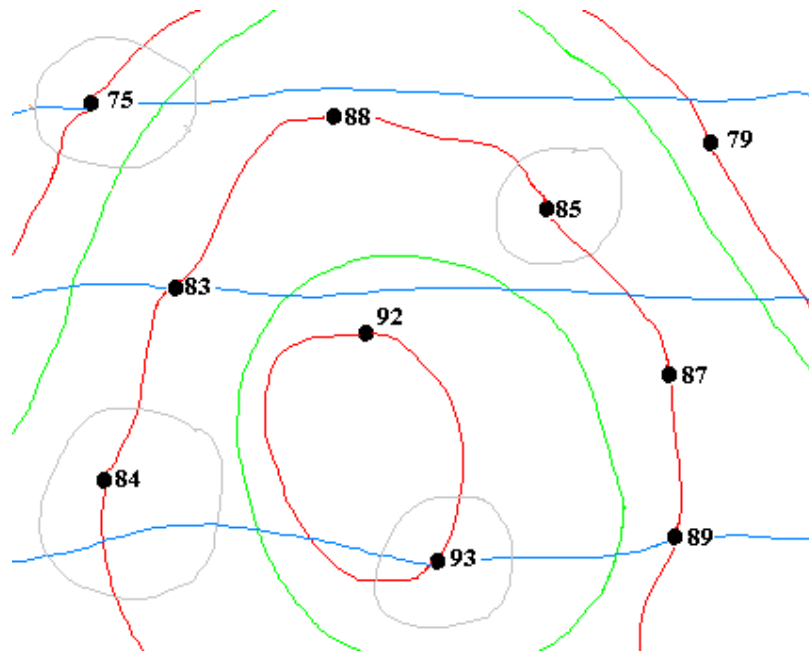
amount of field work involved, cross-section are taken at regular intervals along the centre- line usually where pegs have been established.

- A right angle is set out at each cross-section either by eye for short lengths or by theodolite for long distance or where greater accuracy is needed.
- A ranging rod is placed on either side of the centre line to mark each cross – section.

(3) Contouring

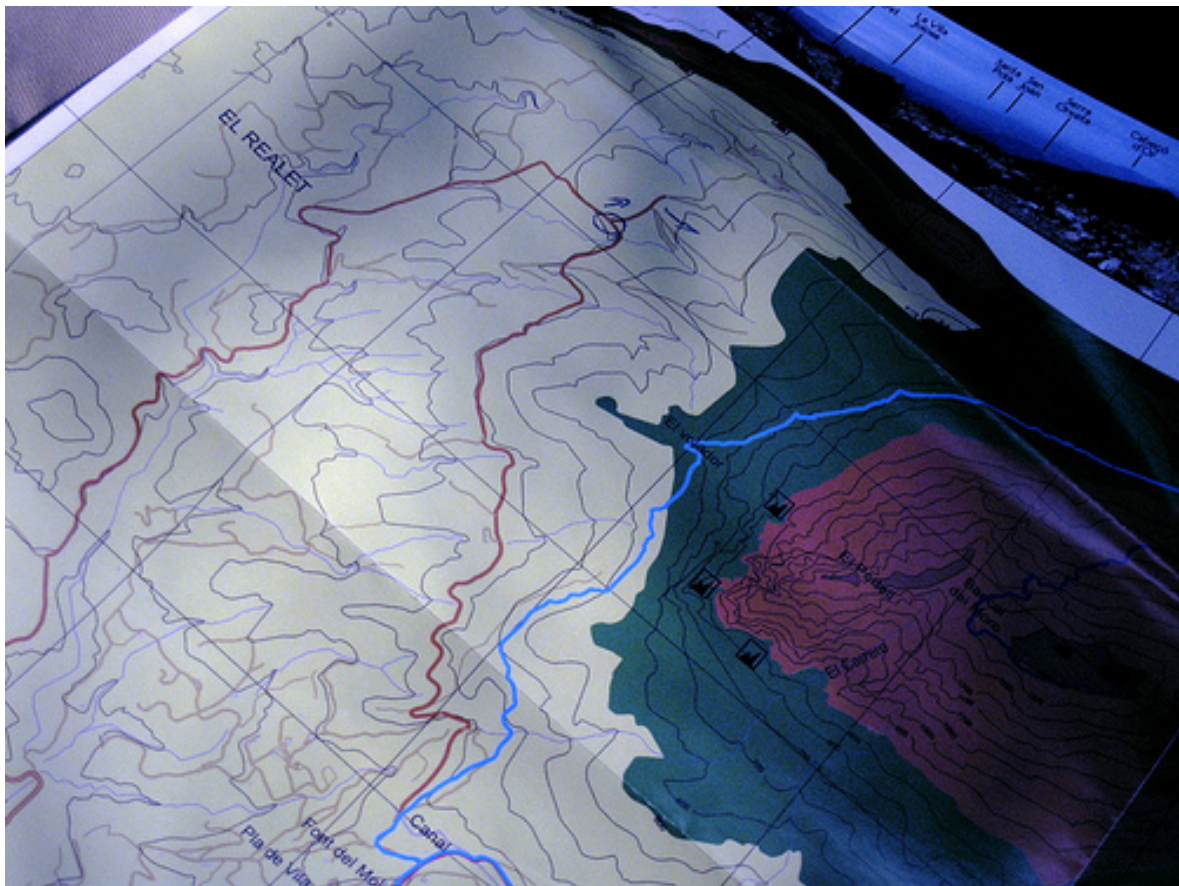


- A contour is defined as an imaginary line joining points of the same height or elevation above or below a datum. These are shown so that the relief or topography of an area can be interpreted (a factor greatly used in civil engineering)



- The difference in height between successive contours is known as the vertical interval (VI) and this interval dictates the accuracy to which the ground is represented. The value of (VI) chosen for any application depends on;
 - (a) Scale of the plan
 - (b) Intended use of the plan
 - (c) The costs involved
 - (d) The nature of the terrain

- Generally, a small vertical interval of up to 1m is required for engineering projects, large scale survey plans and surveys on fairly even sites. A wider vertical interval is used in hilly or broken terrain.
- Electronic instruments such as total stations are normally used to collect data for contouring and contours are plotted by using computer software and hardware.



- If drawn manually, contours can be obtained either directly or indirectly using mathematical interpolation or graphical interpolation techniques.

- **Direct Contouring:**

The position of contours is located on the ground by leveling.

- **Indirect Contouring Method:**

Involves the height of points that do not in general coincide with the contour positions. Instead, the points leveled are used as a framework on which contours are later interpolated on a drawing. The more common methods of indirect contouring involve taking levels either on a regular grid pattern or at carefully selected points.

- **Grid leveling:**

- The area to be contoured is divided into a series of lines forming squares and ground levels are taken at the intersection of the grid lines. The sides of the squares can be 5 to 30m depending on the accuracy required and the nature

of the ground surface. The more irregular the ground surface the greater the concentration of grid points.

- This method of contouring is ideally suited to gently sloping areas but the setting out of the grid on a large area can take a considerable time. Furthermore, if visibility is restricted across the site, difficulties can occur when locating grid points.
- Following the field work, the levels are reduced, the grid is plotted and the contours interpolated either graphically or mathematically, taking into account the general shape of the land as observed during the fieldwork.

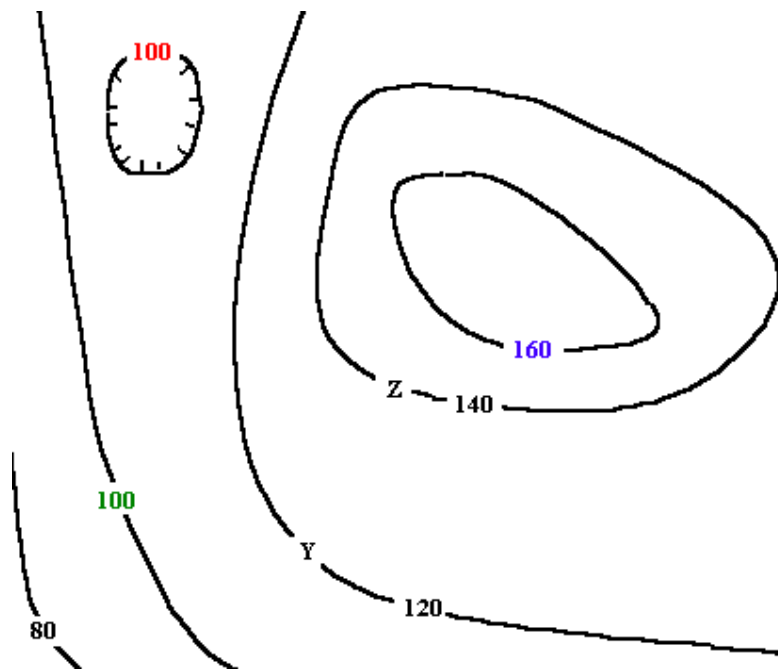
- **Contours from Selected Points**

For large areas or areas containing a lot of detail, contours can be drawn from level taken at points of detail or at prominent points on open ground such as obvious changes of slope. These points will have been plotted on the plan by one of the methods of plotting with the position of each level or spot height forming a random pattern. The contours are drawn by interpolation as in grid levelling.

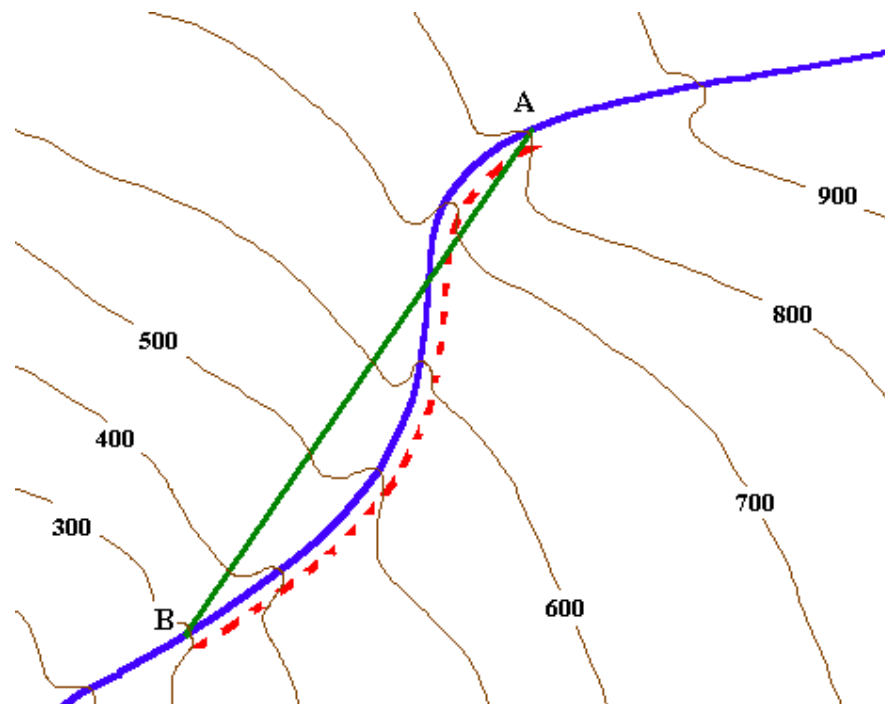
- **Other methods of contouring are;**

- Contouring by section.
- Contouring by radiating lines contouring by tacheometry.
- Interpolating contours.

CONTOUR CHARACTERISTICS



- (i) Contour lines close upon themselves some where each to its own elevation. If not within the limit of the map.
- (ii) Contour lines cannot intersect one another whether they are of the same elevation or not.
- (iii) Contour lines on the tops of ridges and in the bottom of valleys either close or run in pairs within the limits of the map, no single line can ever run between two of higher or lower elevation



(iv) Contour lines indicate uniform slopes when they are equally spaced, convex slopes when they are farther apart with increasing elevations and concave slopes when becoming closer together with increasing elevations

USES OF CONTOUR MAPS

1. Location of possible routes for roads, dams etc.
2. Laying out building sites:
The position of hill tops, basins, steep slopes, etc can be seen from contour plans to avoid siting buildings on exposed hill top and risking possible soil creep, or in basins which may form natural drainage area.
3. Calculation of volumes.
4. Determination of intervisibility between stations.

SOURCES OF ERROR IN LEVELLING

There are five source of errors in leveling and their importance must be appreciated and precaution taken to reduce their effects. These sources includes,

1. Instrumental error in equipment
2. Error in handling the equipments
3. Error due to displacement of equipments
4. Error in reading and booking
5. Error due to natural causes.

1. ERRORS IN EQUIPMENT

(a) Collimation Errors

This can be a serious source of error in leveling if sight length from one instrument position is not equal since the collimation error is proportional to the difference in sight length. Hence in all types of leveling, sights should be kept equal particularly by back sight and the foresights.

(b) Parallax:

This effect must be eliminated before any readings are taken.

(c) Defect of the Staff

- This is possible that staff graduations may be incorrect and new repaired staff should be checked against the steel tape. Particular attention should be paid to the base of the staff to see if it has become badly worn.
- This does not affect height difference if the same staff is used for all the leveling, but introduces some errors if two staffs are being used for the same sources of levels.
- When using a three section staff it is important to ensure that the staff is properly extended by examining the graduations on either staff of each joint. If the joints became loose, the staff should be returned for repair.

(d) The Pod Defect:

The stability of tripods should be checked before any field work commence by testing to see the tripod head is screwed and the shoes at the base of each are not loose.

2. ERRORS IN HANDING EQUIPMENT

(a) Staff Not vertical

Since the staff is used to measure a vertical difference between ground and line of collimation, failure to hold the staff vertical will result in incorrect readings.

(b) Instrument not Level

- For automatic level this source of error is unusual, but for a tilting level in which the tilting screws has to be adjusted for each reading.
- This is a common mistake, the best procedure here to ensure that the main bubble is centralized before and after a reading is taken.

3. ERRORS IN READING AND BOOKING

- Extra care must be taken when reading the staff since an inverted images result in faulty reading being recorded by inexperienced observer, although the image usually diminishes with practice
- Another source of reading error is sighting the staff over too long distance when it becomes impossible to take accurate reading. It is therefore recommended that sighting distance should be limited to 60m, but where absolutely unavoidable this may be increased to a maximum of 100m.
- Many mistakes are made during the booking of the readings and the general rule is that staff sightings must be carefully entered into the leveling table immediately after reading.

4. Errors Due to Displacement of Equipment

- If the instrument is setup on soft or marshy ground, it may settle and alter the height of collimation.
- Change points must be chosen so that when turning the staff round or when replacing it after removal no alteration of height takes place. Always choose stable change points on hard ground and mark the staff position with chalk.

5. Errors due to Natural Causes

- The wind causes vibration of the level, tripod and the staff particularly when it is fully extended thereby making accurate sighting impossible. Always shelter the staff and keep short sights on windy weather. The staff should also be kept short.

- The sun can cause an apparent vibration of the staff owing to irregular refraction. It also affects the bubble by causing unequal expansion of the level and tripod. In hot weather length of sight are reduced to at least 0.5m above the ground through- out the length. The ray-shade in front of the instrument should be extended or shade the instrument with umbrella.
- Rain makes accurate work difficult and unpleasant; rain dropping on the objective glass and condensation on the eye piece make sighting impossible. For precise work it is advisable to wait for better weather condition or ray shade can be used or protecting the instrument with umbrella.

WEEK TEN

THEODOLITES



Theodolites are telescopic instruments used basically for measuring both vertical and horizontal angles. They are also useful in determining horizontal and vertical distances by stadia prolonging straight lines and low order differential levelling. Theodolites are precision instruments used extensively in construction work for measuring angles in the horizontal and vertical planes.

Many different theodolites are available for measuring angles and they are often classified according to the smallest reading that can be taken with the instrument known as the Theodolite Resolution

Theodolite Resolution.

This can vary from 1' to 0.1" and for example, a 1" theodolite is one which can be used read to 1" directly without any estimation.

At this point, it is worth noting that a full circle is 360° and a reading system capable of resolving to 1" directly shows the degree of precision in the manufacture of theodolites.

In order to measure horizontal and vertical angles, the theodolite must be centred over a point using a plumbing device and must be levelled to bring the angle reading systems of the instrument into appropriate planes.

All types of optical theodolites are similar in construction and the general features of the SOKKIA TM20H are shown in figures below.

UNITS OF ANGULAR MEASUREMENT

The units of the angular measurements may be in the form of degrees (sexa-gestimal in the form of degrees, minutes and seconds) in sixty equal divisions, in radians or in grads.

Sexa-gestimal system

Angular measurement have been referred to circles with secondary graduations which sub-divided each degree into 10 minutes or 20 minutes interval. A venire or micrometer sub-divisions then gives the reading down to seconds. The system is referred to as sexagestimal (Latin Sexa genta, sixty) since there are 60 seconds in each one minutes.

A radian

A radian is the angle subtended at the centre of a circle by an arc of the circle equal in length to its radius. That subtended by a circumference of a circle is one complete turn ($2\pi = 360^{\circ}$)

$$2\pi \text{ radian} = 360^{\circ}$$

$$\begin{aligned} \therefore 1 \text{ radian} &= \frac{360}{2\pi} = \frac{180}{\pi} \\ &= 27^\circ 17' 45'' \\ &= 206265 \text{ seconds} \end{aligned}$$

This constant factor is of vital importance in small angles calculations and for conversion of degrees to radians. To convert angles in a radian back to degrees, it is multiplied by $(\pi/180)$

Examples

1. Convert $64^\circ 11' 33''$ to radians

Solution

$$64^\circ 11' 33'' = 231093 \text{ seconds}$$

$$\text{But, 1 radian} = 206265 \text{ seconds}$$

$$\text{Number of radian} = \frac{231093}{206265} = 1.12037 \text{ rad.}$$

$$\therefore 64^\circ 11' 33'' = 1.12037 \text{ radians}$$

2. Convert $60^\circ 5' 21''$ to radian

Solution

$$60^\circ 5' 21'' = 219021 \text{ seconds}$$

$$\text{But, 1 radian} = 206265 \text{ seconds}$$

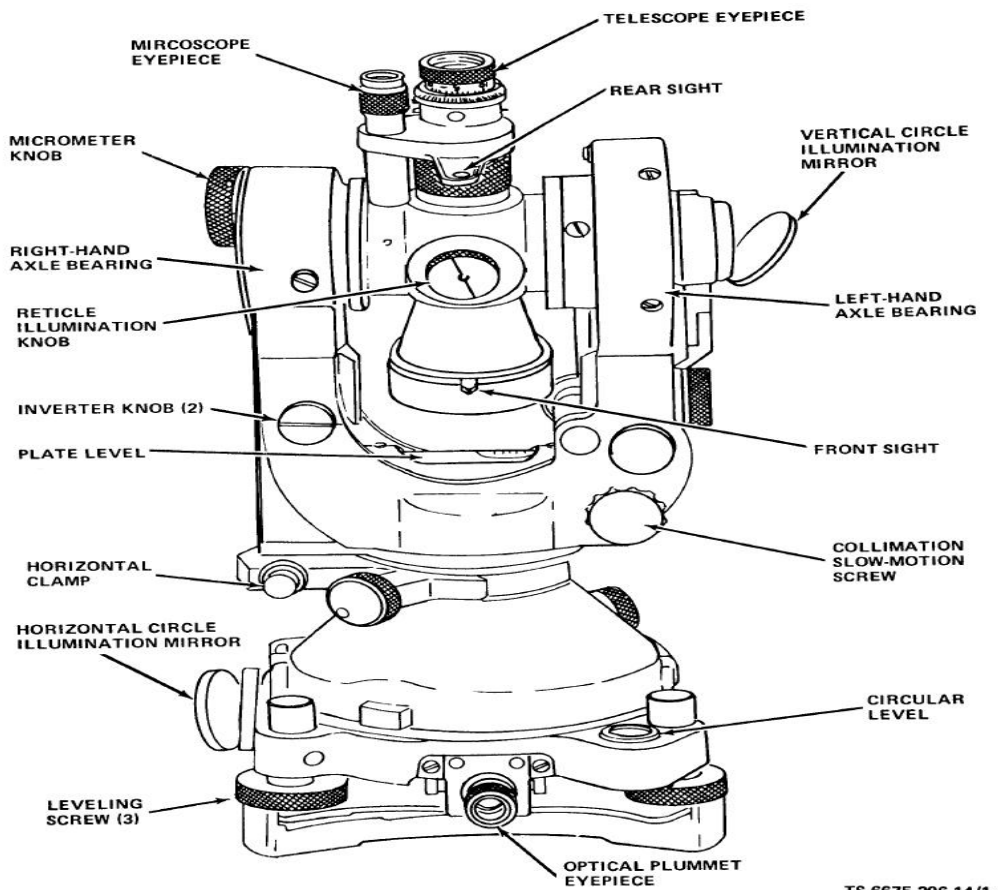
$$= \text{Number of radian} = \frac{219021}{206265} = 1.0684 \text{ rad}$$

$$\therefore 60^\circ 5' 21'' = 1.06184 \text{ radian}$$

BASIC COMPONENTS OF AN OPTICAL THEODOLITE

The various parts of a theodolite and their functions are given as follows;





TS 6675-296-14/1-

Figure 4.2 : Parts of a Theodolite.

Alidade level

Transparent tube that contains liquid and an air bubble; it serves as a guide for positioning the alidade on the vertical axis.

Illumination mirror

Adjustable polished glass surface that reflects light onto the circles so that the angles can be read.

Leveling head

Platform serving as a support for the theodolite.

Horizontal clamp

Knob that locks the alidade to prevent it from rotating.

Leveling head locking knob

Knob that locks the alidade to the leveling head.

Leveling head level

Transparent tube that contains liquid and an air bubble; it serves as a guide for positioning the leveling head on the horizontal axis.

Base plate

Plate to which the leveling head is attached by means of three leveling screws.

Leveling screw

Screw that adjusts the theodolite's leveling head level on the horizontal plane.

Telescope

Optical instrument composed of several lenses; it can be adjusted in the horizontal and vertical planes and is used to observe distant objects.

Optical sight

Device with an eyepiece that precisely aims the telescope at the target whose angles are to be measured.

Adjustment for horizontal-circle image

Knob that adjusts the sharpness of the image of the horizontal circle (graduated from 0° to 360°) in order to read the angles on the horizontal axis.

Micrometer screw

Knob that adjusts the micrometer to give a very precise reading of the circles' measurements.

Adjustment for vertical-circle image

Knob that adjusts the sharpness of the image of the vertical circle (graduated from 0° to 360°) in order to read the angles on the vertical axis.

Alidade

Part of the theodolite that rotates on a vertical axle to measure angles by means of the telescope.

The trivets stage

This forms the base of the instrument and in order to be able to attach the theodolite to the tripod, most tripods have a clamping screw which locates into a $\frac{5}{8}$ inch threaded centre on the trivet. This enables the instrument to move on the tripod head and allows the theodolite to be centred. The trivet also carries the feet of three threaded levelling foot screws.

The tripod

This is used to provide support for the theodolite, the tripod may be telescopic i.e. it has sliding legs or may have legs of fixed lengths.

The Tribrach

This is the body of the instrument carrying all other parts. It has a hollow slightly conical shape socket into which fits the remainder of the instrument. The tribrach can be levelled independently of the trivet stage.

The lower plate

This carries the horizontal circle. The term glass arc has been used to describe optical theodolites because the horizontal and vertical circles on which the angle graduations are photographically etched are made of glass. Many types of optical theodolite are available, varying in reading precision from 1' to 0.1" although 20" and 6" reading theodolites are most commonly used in engineering surveying.

The focusing screw

This is fitted concentrically with the barrel of the telescope and diaphragm can be illuminated for night or tunnel work. When the main telescope is rotated in altitude about the trunnion axis from one direction to face in the opposite direction, it has been transmitted. The side of the main telescope, viewed from the eyepiece, containing the vertical circle is called the face.

Standards

This is the frame mounted directly on the cover plate carrying the telescope.

Transit axis or trunnion axis

This axis rests on the limbs of the standard and is securely held in position by a lock nut. Attached to the transit are the telescope and the vertical circle.

When this is levelled, that is at the centre of its run, the line of sight is horizontal.

Optical plummet

This assists the centering of the instrument particularly in windy weather.

PRACTICAL ON THEODOLITE

AIM:

Carry out theodolite traversing of roads surrounding the school.

APPARATUS:

Theodolite, tripod, steel tape, linen tape, ranging pole, arrows, traverse field book, pegs, nails and bottle cork, pen, protractor, set squares pencil, ink, eraser, scale rule, drawing paper etc.

Personnel

At least six persons in a group

PROCEDURE

- (i) Selection of instrument
- (ii) Test of instrument
- (iii) Field reconnaissance

- (vi) Reconnaissance diagram /sketch
- (v) Setting up the instrument
- (vi) Perform temporary adjustment
- (vii) Observe on both face left and face right
- (viii) Read and book the horizontal circle reading and vertical circle reading on both face left and face right.
- (ix) Measure the distances simultaneously along with (viii). Book the vertical circle reading and horizontal circle reading
- (x) Read and book the three stadia hair readings
- (xi) Reduction of angles
- (xii) Computation
- (xiii) Plot the result at 1:1000 scale

WEEK ELEVEN

COMPASS SURVEYING



Compass surveys are mainly used for the rapid filling of the detail in larger surveys and for explanatory works. It does not provide a very accurate determination of the bearing of a line as the compass needle aligns itself to the earth's magnetic field which does not provide a constant reference point.

THE PRISMATIC COMPASS



This is an instrument used for the measurement of magnetic bearings. It is small and portable usually carried on the hand. This **Prismatic Compass** is one of the two main kinds of magnetic compasses included in the collection for the purpose of measuring magnetic bearings, with the other being the [Surveyor's Compass](#). The main difference between the two instruments is that the surveyor's compass is

usually the larger and more accurate instrument, and is generally used on a stand or tripod.

- The prismatic compass on the other hand is often a small instrument which is held in the hand for observing, and is therefore employed on the rougher classes of work. The graduations on this prismatic compass are situated on a light aluminium ring fastened to the needle, and the zero of the graduations coincides with the south point of the needle. The graduations therefore remain stationary with the needle, and the index turns with the sighting vanes. Since the circle is read at the observer's (rather than the target's) end, the graduations run clockwise from the south end of the needle (0° to 360°), whereas in the surveyor's compass, the graduations run anti-clockwise from north.
- The prismatic attachment consists of a 45° reflecting prism with the eye and reading faces made slightly convex so as to magnify the image of the graduations. The prism is carried on a mounting which can be moved up and down between slides fixed on the outside of the case.
- The purpose of this up-and-down movement is to provide an adjustment for focusing. The image of the graduations is seen through a small circular aperture in the prism mounting, and immediately above this aperture is a small V cut on top of the mounting, over which the vertical wire in the front vane may be viewed. When the V cut, the vertical wire and the station whose bearing is required are viewed in one line, the bearing is directly read off the graduated arc at the point immediately underneath the vertical wire.
- The oblong mirror located in front of the forward vane slides up and down the vane, and is hinged to fold flat over it or to rest inclined at any angle with it. This mirror is used for solar observations, or for viewing any very high object, and is not a normal fitting to a compass. The two circular discs in front of the back vane are dark glasses which can be swung in front of the vane when solar observations are being taken.

COMPONENTS OF A PRISMATIC COMPASS

Prismatic compass consists of a non-magnetic metal case with a glass top and contain the following:

- a. The Pivot:** This is made of hardened steel ground to a fine tip.
- b. The jewel:** It is usually supported by a pivot.
- c. The needles:** Made of magnetized steel which is attached to the jewel.
- d. The compass ring or card:** graduated like a protractor from 0° to 360° in a clockwise direction which is attached to the needle.
- e. A spring brake:** It is operated by the brake pin for damping the oscillations of the needle and card.

- f. **A lifting level:** For raising the card and needle off the pivot when not in use.

OPERATION PROCEDURE

- Remove the corner and open out the prism and window, holding the compass as level as possible.
- Then focus the prism by raising or lowering its case until the divisions appear sharp and clear. If necessary with the needle on to its pivot.
- Holding the compass box with the thumb under the prism (T) and the forefinger near the stud (c), sight through the objector station lowering the eye to read the required bearing as soon as the needle comes to rest naturally (or by simultaneously damping its swings by pressing the stud (c)].
- The bearing read will be a forward bearing and normally a “whole circle” bearing clockwise angle between 0° to 360° .

VARIATION IN DECLINATION

The position of the magnetic poles is not fixed and the North magnetic pole tends to wander more than the south causing alterations in the positions of the isogonic lines from time to time. The angle of declination at any point is therefore not constant subject to the following variations;

1. Secular Variation:

This causes the largest variation in magnetic declination. It is a slow continuous swing with a cycle of about 400 to 500 years. Because of this large movement, the date, the declination and the approximate rate of annual change should be given for any magnetic orientation of survey.

2. Diurnal Variation:

This is a swing of the compass needle about its mean daily position.

3. Periodic Variation:

This is a minor variation of the magnetic meridian during the week, a lunar month, year, eleven years, etc.

- 4. Irregular Variation:** These are caused by magnetic storms which can produce sudden variations of the magnetic meridian.

Magnetic Bearing

The magnetic bearing of a survey line is the angle between the direction of the line and the direction of the magnetic meridian at the beginning of the line.

Magnetic Meridian

- The magnetic meridian at any place is the direction obtained by observing the position of a freely supported magnetized needle when it comes to rest uninfluenced by local attracting forces.
- Magnetic meridians run roughly north –south and follow the varying trend of the earth's magnetic field. The direction of a magnetic meridian does not coincide with the true or geographical meridian which gives the direction of the true North pole except in certain places.

Angle of Declination:

It is defined as the angle between the direction of the magnetic meridian and the true meridian at any point.

Isogonals:

Are lines on a map joining places of equal declination. The isogonic line of zero declination along which the direction of a compass indicates True North is known as an agonic line.

PRACTICAL:

COMPASS SURVEYING

AIM: Carry out compass Surveying of a closed figure, produce the plan and make graphical adjustment.

APPARATUS:

Prismatic compass, steel tape, linen tape, ranging pole, arrows, chain survey field book, pegs, nails and bottle cork, protractor, set squares, pencil, ink, eraser, scale rule, drawing paper etc.

Personnel

At least six persons in a group

PROCEDURE

- Selection of instrument
- Test of instrument
- Remove the corner and open out the prism and window, holding the compass as level as possible.
- Then focus the prism by raising or lowering its case until the divisions appear sharp and clear. If necessary with the needle on to its pivot.
- Holding the compass box with the thumb under the prism (T) and the forefinger near the stud (c), sight through the objector station lowering the eye to read the required bearing as soon as the needle comes to rest naturally (or by simultaneously damping its swings by pressing the stud (c)].
- The bearing read will be a forward bearing and normally a “whole circle” bearing clockwise angle between 0° to 360° .

- Running the compass survey round the figure
- Read and book bearings
- Measure the distances and book
- Reduction and computation
- Plotting (using scale 1:500).

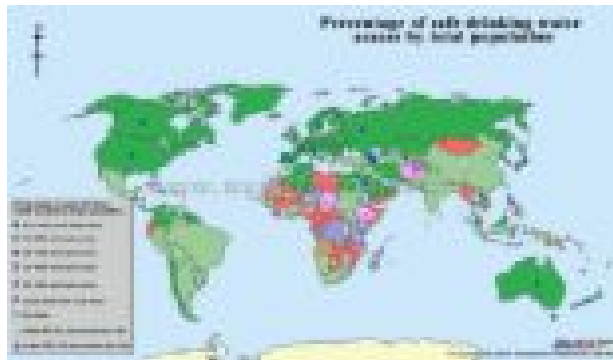
WEEK TWELVE

INTERPRETATION OF MAPS, LAYOUT AND ENGINEERING SURVEY PLAN

Maps and Plans

The presentation of the measurements made in land surveying is in the form of maps, plans or diagram with the information recorded in a suitable manner on the drawing by the scale representation, use of conversional signs, tabulation of notes, etc. The most suitable method of representing the information depends on the nature of the survey work.

- On maps, the scale is too small to allow every feature to be properly presented to scale. Thus conversional symbols are used to represent feature which would otherwise be too small to be recognized.



- Plans on the other hand show all features on the ground correctly to scale. Symbols or methods are used to represent ground features on a plan. Different organizations have slightly different conversions for representing detail on plans, but the best are those forms which are simple, clear, and can not be misinterpreted.

TYPES OF MAPS

There are different types of maps namely:

1. Geographical maps
2. Atlas
3. Topographical maps
4. Engineering maps

GENERAL REQUIREMENT OF A MAP OR PLAN



- (a) The title
- (b) The scale
- (c) The North Point (north direction)
- (d) Border lines
- (e) An explanation or legend, as to the symbols employed.
- (f) A terrier, showing the acreages held by various owners
- (g) The surveyor's sign.

Special requirements include:

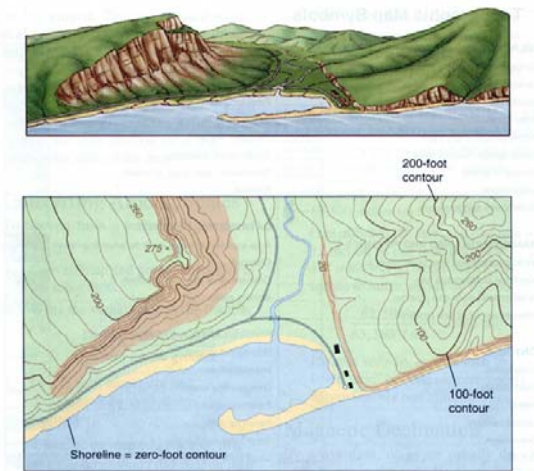


FIGURE 6.7
 The area sketched in the top diagram is shown as a topographic map in the bottom diagram. Contour lines on the bottom diagram are drawn at intervals of 20 feet, starting with 0 at mean sea level. SOURCE: U.S. GEOLOGICAL SURVEY.
 (Adapted from Jones, 2001: Laboratory Manual for Physical Geology, 3rd Edition.)

- (h) Contours, bachures or spot levels.
- (i) Constructional lines and symbols for building and civil engineering works.
- (j) Location of the survey

- (k) Details of the control grid used

MAP SCALES

The scale of a map or plan is the ratio of ground length (distance) to the map or plan length on paper. Thus a scale of 1:000 indicates that one metre on the paper represents 1000metres on the ground.

Scales of this category are drawn on the map to facilitate measurement with a paper strip or a pair of dividers and to provide against the shrinkage of the paper over the lapse of years.

Types of scales include:

- **Comparative scales**

Comparative scales show two different systems such as feet and metres on the same representative fraction or statement. This can be in the form of Imperial scales (under the imperial old system scale) represented by a length in inches on paper being equivalent to a distance in some other unit on the ground.

Example;

- 1 inch = 66ft. or 6in = 1 mile etc.

Metric scale are usually preferred with a

- Basic scale of 1:1250, 1:2500 and 1:10,000 for a large scale maps.
- Small scale maps; scales of 1:50,000, 1:25000, 1:50,000, 1:100,000 are used.
- For site plans, a scale of 1:500, 1:200, 1:100 or 1:50 are used.
- Detail plans scales of up to 1:20, 1:10, 1:5 or 1:1 (full size) may be used.

Time scale

Time scale show time interest instead of yards, feets or metres for a given statement or representative fraction. It is used in military surveying or exploratory mapping.

Diagonal Scale

This is a form of scale which allows measurement to a higher degree of accuracy than on a normal scale. Instead of estimating the distance between small graduations a diagonal is extended upwards to provide an enlargement of the space.

PRINCIPLES OF PLAN PRODUCTION

When producing a hand drawn plan, the procedures involved include;

- (1) The accuracy of the survey is specified
 - (2) Suitable drawing paper or film is chosen.
 - (3) An accurate co-ordinate grid is established on the drawing paper or film at the required scale and the control network is plotted.
 - (4) The positions of the features in the area located on site are plotted on the drawing
 - (5) Once the detail has been plotted, the plan is completed by adding a title block containing the location of the survey, a north sign, the scale, the date, the key or legend and other relevant information.
- In practice, if a hand drawing is being produced, the original survey plan is usually prepared in pencil by surveyor who undertake the field work known as the master survey drawing, when it has been completed, the master drawing is then traced in ink onto plastic film by a trained draught man,
 - During the tracing stage, other relevant information is added to that shown on the master drawing to produce the completed survey plan.

Computer aided drawing are being produced with a computer software on special multi-pen plotters. A wide range of such software and plotters is now available which enables survey plans to be produced very quickly to a high degree of accuracy.

- For example, field survey information is stored in a data base to prepare a three –dimensional representation of the ground surface known as a digital terrain model (DTM).
- Using the data base and the DTM, plans, contour overlays, sections and perspective views can be obtained at virtually any scale.
- If a computer aided drawing is being produced then any additional relevant information can be programmed into the finished drawing and viewed on the computer screen before the final plan is plotted.

WEEK THIRTEEN

MEASURING DISTANCE FROM MAP OR PLAN

In order to obtain the distance between two points represented on a map or plan, the procedure is simply to mark off the distance between the two points with a pair of dividers or with the straight edge of a piece of paper and transfer it to the scale bar or diagonal scale and read off the distance. If a scale graduated to the scale of the map is available the distance on map is read off directly.

ORIENTATION

In order to establish direction of a given print on a map or plan, a line is drawn between the two points and the angle which the line makes with some fixed reference direction is measured. Every map or plan therefore indicates the direction of this reference point usually towards the top of the drawing sheet which may be one of the following.



- (a) The direction of True north
- (b) The direction of magnetic North
- (c) The direction of any arbitrary line between two feature on the drawing

Measuring areas from the survey plot (Map or Plan)

Area can be calculated from a survey plot (map or plan) in one of the following ways;

- (a) By dividing the plot into geometrical features (triangles, squares or parallel strips) and calculating the area of each from scaled dimensions.
- (b) By scaling ordinates across the figure and calculating the area by Simpson's rule or the trapezoidal rule.

- (c) By using a planimeter, which allows the area to be obtained mechanically from reading off a graduated measuring unit.

MEASURING AREA BY THE PLANIMETER

This instrument is used to measure area mechanically on plans. It has the following components



- (i) Pole arm
- (ii) Tracer arm
- (iii) Tracer point
- (iv) Measuring wheel (measuring unit)

Area measurement from drawings, by planimeter is efficient and fast, particularly if the areas are small or very irregular in shape. The forms of planimeters used in survey are;

- Polar planimeters
- Fixed arm polar planimeters
- Sliding bar planimeters. etc.

(i) The tracer arm: Is fitted at one end to the measuring unit which may be fixed on a movable carriage, and at the other end supports the tracer point for tracing the circumference of the area to be measured.

(ii) The pole arm: This rotates about a needle pointed weight or pole block. The other end of the pole arm carries a pivot resting in a socket and the carriage fixed to tracer arm.

(iii) The measuring unit: Consist of a hard steel measuring wheel attached to a drum graduated into tenths and hundredth and geared to a revolution counter. A vernier index against the drum allows readings to be taken directly to one-thousand of revolution of the measuring wheel.

The operation or simplest application of planimeters involves two methods as follows:

- With the pole block placed outside the area to be measured (the usual and more convenient method).
- With the pole block placed inside the area to be measured (used for areas too large to be measured conveniently by the first method).

Planimeter operation procedure

- The carriage is set as necessary for the scale of the drawing and attaches the pole arm to the tracer arm.
- Having fixed the pole block suitably, place the tracing point on a mark on the outline and read the vernier.
- Follow the outline of the area to be measured carefully with the tracing point in a clock –wise direction returning to the starting point.
- Read the vernier again. The difference between the readings is proportional to the area measured.
- The process is repeated several times until at least three consistent readings are obtained and the mean is taken.
- If the block is outside the figure simply multiple the result by the scale factor to produce the area.

Example

Using a fixed arm planimeter with the pole outside the figure. The following readings were recorded on a fixed arm planimeter, where one revolution of the measuring wheel represented 100cm^2 when measuring an irregular area on a plot to a scale of 1.500.

What is the ground area?

<u>Initial reading</u>	<u>Final reading</u>	<u>Difference</u>
0.160	2.173	2.013
2.173	4.188	2.015
4.190	6.204	2.014

Solution

The mean reading is $\frac{2.103 + 2.015 + 2.014}{3}$

$$\begin{aligned}
 &= 2.014\text{m} \\
 \text{Each revolution} &= 100\text{cm}^2 \\
 \therefore \text{The area on the plot} &= 2.014 \times 100 \\
 &= 201.4\text{m} \\
 \text{At a scale of 1:500; } 1\text{cm}^2 &= \frac{250,000}{10,000} = 25\text{m}^2 \text{ on the ground.}
 \end{aligned}$$

$$\begin{aligned}
 \text{Area on the ground} &= 201.4 \times 25\text{m}^2 \\
 &= 5035\text{m}^2 \\
 &= 0.504\text{ha}
 \end{aligned}$$

PLAN DISTORTION

If measurements are made on plans with a scale and the plans are known to have shrunk or stretch, allowance will have to be made for the alteration in scale, if the amount of distortion is known.

Example:

A plan plotted to a scale of 1:2500 was found to have shrunk causing a line plotted 300mm long to now measure 296mm. A distance was measured on the plan and found to be 198mm long. What is the true distance on the ground?

Solution: -

Original scale = 1:2500

The scale is no longer 1:2500, hence the new

$$\text{Scale is } 1:2500 \times \frac{300}{296} = 1.2534$$

The measured distance on the plan = 198mm. Hence,

$$\begin{aligned}
 \text{True distance on the ground} &= 198 \times 2534 \\
 &= 501.7\text{m}
 \end{aligned}$$

Example

A plan, plotted to a scale of 1:500 was found to have stretched by 1%. A line scaled on the plan produced a distance of 227.5m. What is the true distance?

Solution: -

Let the true distance be x

$$\text{Original scale} = 1:500$$

Since the scale is stretched by 1%, it should be subtracted from the original scale.

$$\frac{1}{100} \times \frac{500}{1} = 5\text{mm}$$

$$\text{New scale} = 500 - 5\text{mm} = 495\text{mm}$$

$$= 1:495$$

$$\frac{\text{New scale}}{\text{Actual scale}} = \frac{\text{True distance}}{\text{Shrunk length}}$$

$$\frac{495}{500} = \frac{x}{227.5}$$

$$\therefore x = \frac{495 \times 227.5}{500} = 225.23\text{m}$$

$$\therefore \text{The true distance (x)} = 225.23\text{m}$$

EXERCISE:

- (a) A field plan of an area of 17.436 hectares covers 27900mm² on paper. What is the scale?
- (b) A plan plotted to a scale of 1:250 was found to have stretched by 2%. A line scaled on the plan produced a distance of 227.5m. What is the true distance?

WEEK FOURTEEN

THE NATIONAL GRID

The National grid is an imaginary network of lines parallel to and at right angle to the central meridian of the projection so forming a series of square on the maps. They are in a form of rectangular co-ordinates system device for the following purpose.

- Plotting
- References
- Classification

- **Plotting:** It forms the basis for plotting the complex curves and the position of co-ordinated survey stations.
- **Reference:** It provides a unique reference for any figure shown on the maps whereby such features can be located with accuracy. The grid is therefore sufficient for most people to device a simple reference system for their own purpose.
- The grid network is based on the longitude origin of the projection, 2° west. Lines are established parallel and at right angles to this line 100km apart.
- Measurement east of the origin are considered positive and west as negative with a false origin created 400km west of the origin.
- To prevent the need for large co-ordinate value, each grid square is identified by a pair of capital letters.

- The grid is first divided into major 500km² each which is identified by letters (A, B, C, D, E) with each major square divided into twenty five 100km² littered alphabetically as shown below

Diagram

- **Classification:** All the maps of the ordinance survey can be fitted into the grid system in a precise manner and the grid reference of a point shown on any one map is the same of all other maps of different scales.

Note: The following are the unique map and plan referencing systems.

- (a) **SP 52:-** Two letters two numbers (1:25000) scale.
- (b) **SP S2 NE:** Two letters, two numbers and quadrant (1:10,000 scale)
- (c) **SP 5622:-** Two letters and four numbers (Four figure reference 1: 2500 scale plan).
- (d) **SP 5622SE:-** Two letters four number and quadrant. – The 1: 12500 scale plan.
- (e) **SP 565225:** Six figure reference.

WEEK FIFTEEN

SUBMISSION OF SURVEY RECORDS

The following survey information must be submitted by the surveyor to the survey department or local authority in respect of each survey carried out,

- (a) Plan on mounted paper (and a tracing on transparency).
- (b) A work diagram showing how the survey was run.
- (c) Field book which should contain neatly drawn simple diagrams showing the course and relevant turning points.
 - If a wrong figure is written or if it is found necessary to alter any measurements, the erroneous figures should be neatly crossed out (not deleted) and the correct ones written above.
 - To guard against fraud, such alterations should be signed by the surveyor or booker.
 - All bookings must be done in ink or ball point not be torn out of field books. A signed honour certificate at the end of each book is necessary as follows:
“I certify that the figures in the foregoing field notes are the actual figures recorded by me as a result of my measurements and observation in the field and that the survey was made in accordance with regulations.”

(d) Computations.

A survey report giving a brief, description of the method of survey carried out, total length in metres and boundary lines, the types of country, any cause of delay incurred and any contacts with chief or land owners during the survey.

PRESERVATION OF SURVEY RECORDS

Survey records are preserved by the local authorities as follows:

1. Maps/Plans

- The survey regulation require that a copy of all plans, maps or diagrams which are prepared by any surveyor (public or private) must be lodged with the surveyor General of the State or his representative where the land is situated.
- Private surveyors will be issued with a certificate of deposit on payment of certain charge.
- All the maps/plans/drawing are expected to be kept good and safe within the survey department ensuring that they are made available for public inspection on request.

2. Public inspection on request (Co-ordinates)

Each state survey department maintains a co-ordinate register where the co-ordinates of all cadastral control points and those of properties within the state are recorded. These are expected to be made available to the public on request. National frame work control co-ordinates are usually available at the Federal Survey Department.

3. Priority Sheet (intelligence Chart)

This show application and grants of certificates of occupancy. It serves as a guide for prospective land seekers in finding at a glance spot of unoccupied sites in any locality of choice.

4. Beacons Description

Beacons description could be of extreme value if good advantages of their existence could be taken by the owners or occupiers of lands boundaries where they are placed and those charged with the responsibility of providing the public with utilities (water, electricity, telephone etc).

The law imposes a penalty on land owner or occupier who fails to report any case of willful obliteration, removal or injury to any such beacons.

5. Township Map Index

Each town or city should be covered by a number of large scale map sheets identified by numbers for easy reference. Township map indices are done at

compilation state, fair drawing stage and those at reproduction stage usually distinguished by different colours.

6. Base lines information

These include the standard length of bases, the temperature at which they have been determined, and the materials used for the erection of such bases. Licensed surveyors are expected by the survey regulations to obtain a certificate of standardization for their tapes at least once every year on payment of stipulated fee.

7. Field Books Computation Sheets and Survey Records

These are usually kept together in a folder for each survey and keep in a record room in the survey department along with such other related information.